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IN THIS ISSUE:

PRINCIPLES GOVERNING WATER-FINDING

AGRICULTURAL EXTENSION METHODS AMONG AFRICAN PEASANT FARMERS

USE OF TRANSPORT AND POISON BAIT IN A LOCUST CAMPAIGN

WHEAT EXPERIMENTS IN NORTHERN PROVINCE, TANGANYIKA

HIDES AND SKINS INDUSTRY—PART I

OBSERVATIONS ON SPACING OF SISAL

GROWTH AND BEARING HABITS OF COFFEA ARABICA

INDEX TO VOL. XI

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Readers are reminded that all agricultural inquiries, whether they relate to articles in the Journal or not, should be addressed to the local Director of Agriculture, and not to Amani.

CONTENTS

	PAGE
Modern Methods of Water-finding	195
Principles Governing Water-finding (E. Parsons)	197
Agricultural Extension Methods Amongst African Peasant Farmers (G. B. Masefield)	214
Correspondence	221
The Use of Transport and Poison Bait in a Locust Campaign (R. J. M. Swynnerton)	224
Results of Some Wheat Experiments in the Northern Province, Tanganyika Territory (N. R. Fuggles-Couchman)	231
Notes on the Hides and Skins Industry—Part I (M. H. French)	238
Observations on the Spacing of Sisal (G. W. Lock)	247
Growth and Bearing Habits of *Coffea arabica* in Kenya and in Southern India (R. W. Rayner)	251
Land Tenure and Colonial Development: A Review	255
Index to Volume XI	

INDEX TO ADVERTISERS

	PAGE
African Mercantile Co., Ltd.	Cover page 3
Arthur A. White, Ltd.	XVIII
Barclays Bank (D.C. & O.)	VII
Baumann & Co.	VIII
Bovill, Matheson & Co., Ltd.	XX
British India Steam Navigation Co.	XVI
Craelius East African Drilling Co., Ltd.	VII
Dalgety & Co., Ltd.	XIV
Dunlop Tyres	Cover page 4
East African Breweries	X
Gailey & Roberts, Ltd.	XII
Johnnie Walker	VI
Imperial Agricultural Bureaux	XV
Kenya & Uganda Railways & Harbours	III
Kenya Farmers' Association (Co-operative), Ltd.	I
Kettles-Roy & Tysons (Msa.), Ltd.	II
Macgregor-Oates Motors, Ltd.	IX
Markham & Co., Ltd.	XVII
Mitchell Cotts & Co.	Cover page 2
Motor Mart & Exchange, Ltd.	XI
National Bank of India, Ltd.	V
Ndurumo, Limited	XVIII
Nyasaland Agricultural Journal	Cover page 3
Sisal Products (East Africa), Ltd.	IV
Smith Mackenzie & Co., Ltd.	VI
Standard Bank of South Africa, Ltd.	VIII
Uganda Company, Ltd.	XIII
Vithaldas Haridas & Co., Ltd.	V

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THE EAST AFRICAN AGRICULTURAL JOURNAL

Issued under the Authority of the East African Governors' Conference and published every three months—July, October, January, April. Volume consists of four issues (commencing July issue).

MODERN METHODS OF WATER-FINDING

C. Gillman has emphasized in numerous lectures and articles that the key factor in the expansion of agriculture in Tanganyika is the supply of domestic water, and J. Glover, in the previous number of this Journal, showed that by choosing the most suitable crops, even the semi-arid areas can be agriculturally productive. It is therefore of particular interest that we publish in this issue an article by Dr. E. Parsons on the principles of water-finding. In looking for underground water supplies the geologist has only a few pieces of a jig-saw puzzle, and he has to put these in their proper places in order to find the general picture and to know the shape of the missing pieces. At first sight there appears to be a certain amount of guess-work in water-finding, but it is really a specialized form of acute reasoning which permits a geologist to work out the relations and characteristics of the underground rock formations and to judge the most likely places for well-boring.

Parsons makes a passing reference to the old-fashioned dowser with his magic twig, and it is pleasing that he does not decry completely the art of dowsing. Dowsing was the only form of advice available for many hundreds of years, and the genuine dowser must have done much to improve water supplies, even although he may not always have been successful. That there is "something in it" is seen from the recent work of two scientific investigators, who examined the art of dowsing for the Dowsing Society. They proved that the muscles of animals and humans may act like a galvanometer in recording variations in electric and magnetic fields. In the discussion on Parsons' article,* which was delivered at a lecture to the East African Association of Engineers, no support is given to his suggestion that there may be something to be said for dowsing, but the fact remains that before the geologists applied their science to water-finding, the dowser occasionally, if not frequently, found water to assist in the development of agriculture.

The modern dowser is either a geologist or a geophysicist, collaboration between the two being the ideal. The geologist works out the conformation of the underground strata, and looks for places where a subsurface impervious layer has allowed water to collect in a basin, or has given rise to an underground "stream" which can be tapped at a suitable point. The water occurs in water-logged strata, such as sand overlying clay, and it is the steady underground seepage from the surrounding country which maintains a regular supply. Parsons shows how faulting of the rocks can confuse the interpretation of the geological evidence, and how instances can occur where water can be side-tracked by abnormal geological formations.

The geophysicist attacks the problem from a different angle from that of the geologist, and to the layman his methods are sufficiently mysterious to remind him of the art of the water-diviner. With his torsion balance he "weighs" the underground geological formations, and by means of rather abstruse calculations he can obtain a picture of the general shape of the underlying geological structures. Of all geophysical equipment the torsion balance is most reminiscent of the diviner's rod, since to the ordinary eye it looks like a simple plumb weight suspended on a six-foot wire. But when we find that it takes 24 hours to become steady, and that it is affected by every small undulation in the ground for a radius of several yards, the extreme delicacy of the instrument becomes apparent. Its movements—for it is never quite still—are affected by the underlying geological formations, and by photographing these minute movements the geophysicist has sufficient data to enable him to "weigh" the rock strata and to obtain some information on the densities of the successive layers.

---

* The discussion will be published in the July, 1946, number of this Journal.

Seismographic methods are easier to understand in general principle, since they involve exploding charges of dynamite at different depths, in order to create miniature earthquakes, and by means of a ring of delicate recording instruments the rate of movements of the shock through the different rock layers can be measured. But the interpretation of these seismographic records can only be done by an experienced geophysicist, who must also have access to detailed geological information on the area.

Perhaps the most fascinating of these geophysical methods is the Schlumberger apparatus, used mainly in oil boring. Formerly cores of rock were brought to the surface at intervals in boring, and examination by geologists enabled the succession of strata to be identified. The Schlumberger apparatus is virtually an "electric eye", which continuously maps the formations as it is lowered into the borehole. The principle is that an electrode is placed on the surface some distance from the borehole, and another is lowered into the drilling mud. As this second electrode is lowered into the borehole, a current is passed between the two electrodes, and the varying density of the rock strata affects the electrical resistance between the electrodes. When the electrode comes to a water-bearing or oil-bearing layer the resistance drops markedly and the continuous record shows a peak. The reaction is so sensitive that it is possible to distinguish between water and oil, and it would probably be possible to distinguish between salt water and fresh water, since the high conductivity of the former would give a much lower resistance than with fresh water. The method is at present suitable only for the very deep drilling of oil wells, and it has not been applied to water finding.

H. J. R. Way of the Uganda Geological Survey has used an electrical method for water-finding which is simple, rapid, and effective in giving information on the potential water supplies of relatively large areas. If two metal spikes are driven into soil and a current is passed between them, the resistance of the soil to the passage of the current will depend on its moisture content. Dry soil will show a high resistance, moist soil a low. But the current not only passes in a straight line between the spikes, it also moves in a curve which penetrates the soil to a depth approximately equal to one-third of the distance between the spikes. Thus by placing the spikes 50 feet apart a subsurface water supply at a depth of 18 feet can be found, and by increasing the distance between the spikes greater depths can be investigated. Theoretically there is no limit to the depth at which the method can be applied, but Way found that the efficiency of the recording apparatus limited him to a maximum distance of 1,500 feet between the electrodes, i.e. a depth of 500 feet. The actual measurements of resistance are not carried out directly between these two spikes, as this is not possible for technical reasons. Two other spikes are placed between the first two, so that all four are in line and equally spaced. By measuring the current between the two inner spikes which are picking up the current between the outer spikes, interfering factors are eliminated and small variations can be accurately recorded.

The field application is simple, but Way points out that a knowledge of the geology of the area is essential in order to judge the most suitable distance apart for the electrodes, and therefore the depth to which the current will penetrate. Having selected a suitable depth, say 33 feet, with the spikes 100 feet apart, a traverse is carried out by taking measurements at regular intervals such as 100 feet. A sharp drop in the resistance at any point indicates the presence of water in the soil or rock and by experience coupled with knowledge of the geology it is possible to judge whether or not this would be a suitable site for a well or borehole.

Thus the geophysicist "weighs" the underlying strata with his torsion balance, measures their resistance to explosive shock with his seismographic apparatus, or uses their variations in electrical resistance to identify their geological sequence. Parsons gives an example of how a geophysicist can be misled without complementary geological evidence, but we feel it only fair to tip the balance the other way with an example of how geologists can be misled. In one bauxite field the geological evidence pointed to a large deposit of commercial ore, but the geophysicist "weighed" it in his balance and found it wanting. The geological evidence was so convincing that the company decided to open up the deposit, but after a comparatively short life it petered out, or became so patchy that it did not pay to continue mining.

D.W.D.

CORRECTION

Page 170, Vol. XI, No. 4, January, 1946, last line: *Delete* "Spear grass (*Heteropogon contortus*)".

PRINCIPLES GOVERNING WATER-FINDING

By Dr. E. Parsons, D.Sc., F.G.S., M.Inst.M.M.

(*An address given to the East African Association of Engineers on* 6*th November,* 1945)

INTRODUCTION

This subject is one that should be in the forefront with all residents of East Africa. All engineers of whatsoever branch are, or should be, interested in it. The mechanical engineer finds his major interest in the control of water in pipes, pumps, etc., and in its effects on his boilers; the civil engineer in its storage and delivery to points of usage, its control in flood and the protection of engineering works from its devastating power; the electrical engineer is mainly interested in it as a source of power; the mining engineer is concerned with its excess underground, and its shortage or unsuitability in the mill; the chemical engineer finds his interest principally with water as a solute.

We in Nairobi in particular and in East Africa in general have heard much of the failing supplies of water. To our City Fathers and to many farmers alike it has given many a headache; and that not because of the lack of it as a dilutant. What the riparian owners of East Africa would do without this eternal source of grouse against their neighbours, one cannot imagine.

This paper is more concerned with the problems of the finding and location of water supplies and the principles, which must be understood in order to enable one to bring them to the service of man. It is viewed principally from the geologist's point of view. The geologist is undoubtedly the one most suited by training and experience to undertake the initial work of water finding. This requires a knowledge of meteorology, hydrology, lithological and structural geology, tectonics, physiography, not to mention the basic sciences of physics and chemistry. Some aspects of it, more especially on the conservation side, call for an intimate knowledge of botany. The mechanical engineer, with his knowledge of power units, pumps, etc., is essential to put the water where it is most required. The civil engineer, with his acquaintance of the strength of materials, is vital in connexion with its storage and control.

Any water-supply problem should therefore be the work of a team comprising geologists, civil and mechanical engineers. The geologist's function is to find suitable underground reservoirs, the cause and control of the springs, to locate dams, wells, boreholes, etc. A geological reconnaissance should certainly precede any effort to provide permanent water. This fact has been recognized by authorities as the following quotations testify:—

Mr. Beeby Thompson, writing some years ago on the water problems of Kenya, writes:—

"Until recently water supplies (in Kenya) have been almost entirely confined to the collection of surface water from rivers, streams, or springs, and it is the natural procedure in new countries to utilize obvious and visible sources in preference to exploring unknown and uncertain aquifers calling often for expert geological knowledge and mechanical appliances."

Similarly Mr. Gillman in his study of the Tanganyika water problem writes:—

"A great variety of structure and geological formations with many types dovetailing into one another, is thus the outstanding characteristic of the country; an intricate pattern that must be clearly understood if one wishes to gauge its cumulative influence on climate and hydrography."

CLASSIFICATION

The scientist invariably seeks to classify everything with which he has to deal. But it must be remembered that classifications are man-devised schemes to group and simplify facts. Nature knows no hard-and-fast divisions, one group gradually merging into another so that it is often impossible to allot many cases to any particular class.

All water as regards its origin may be grouped as either (*a*) *meteoric* or (*b*) *plutonic*. As the name meteoric implies, such waters are derived from the atmosphere. Plutonic waters are primeval waters released from the inner portions of the earth's crust by separation from rock magmas and by oxidation processes. They are often called *magmatic* or *juvenile* waters.

Both classes may pass the one into the other or become mingled. In many cases it is difficult, if not impossible, to decide whether a certain water supply is of meteoric or of "juvenile" origin. This difficulty may be illustrated by the following quotations:—

Beeby Thompson wrote:—

"The Rift Valley in particular, offers almost unlimited scope for detailed investigation, as along this great belt of faulted country the flow of groundwater is influenced by a whole series of unusual and obscure conditions only imperfectly understood. The very nature of the forces causing the rifts is in dispute, some supporting a compression theory in opposition to the generally accepted tension explanation. . . . . A few boreholes sunk near volcanoes in the Rift Valley have yielded hot or boiling water, *apparently the result of meteoric waters meeting deep-seated volcanic dust or scoria which has not yet cooled*." (Italics mine.)

On the other hand, Dixey in his handbook writes:—

"Hot springs are found in many localities that have not recently been affected by vulcanism. Some of these have large flows and issue at temperatures near the boiling point. In many cases their waters are probably of plutonic origin and arise from condensation of aqueous vapours discharged from igneous rocks at great depths; they are forced upwards by high gas pressures, and are sometimes augmented by meteoric waters encountered by the way. Such springs accordingly may flow more abundantly, but at a lower temperature, when the enclosing rocks absorb fresh supplies of rain water. Hot springs are known in Africa at numerous places, many of which lie along the line of the Rift Valley. Most of these are known to be more or less directly connected with fault lines or related to recent volcanic activity. . . Hot springs are known in Tanganyika Territory along the railway; they rise along fractures and are considered to come from a depth of 1,200–1,600 metres. They have been shown to be independent of rainfall and individually to be uniform in temperature and composition."

It is clear that each hot spring must be studied and considered on its own merits before deciding whether or not the water is of meteoric or of juvenile origin.

An interesting case, which deserves careful study, is that of the steam jets on Eburru, near lakes Naivasha and Elmenteita. It has been suggested that these are juvenile or magmatic waters rising from the vents of the old volcano. On the other hand, they may quite reasonably be due to the percolation of the waters of lakes Naivasha and Elmenteita along fault zones under the lakes into the heated zone underlying the now quiescent Eburru volcano, and the rise of the resulting steam up fault planes on Eburru. This may account for the drop in the levels of these lakes, and for the freedom of Lake Naivasha from excessive saline content. Equally it may explain the prevalence of the hot springs of Njorowe Gorge, while steam jets occur on the higher reaches of Eburru, where the waters have to travel through a greater thickness of the earth's crust.

It must be realized that waters of both these classes may be found in nature as either surface or underground waters. Juvenile waters are more prevalent where recent tectonic movements have taken place, and usually in association with vulcanism. They are often rich in minerals and frequently have medicinal qualities. The large rain clouds found over active volcanoes and the large volumes of steam, which are associated with volcanic outbursts, are indications of the presence of magmatic waters.

HYDROLOGY

This is the science concerned with the geological and geographical distribution of water, its availability, its dispersion, and practically every aspect of water in its relation to the country and to man.

Hydrologists recognize a "hydrological cycle". Being a cycle, the starting point is largely a matter of choice. We are in the same difficulty as the biologist in regard to the question of which came first, the hen or the egg! Shall we regard rain as the source or the seas from which it is evaporated?

Starting with rain we get in addition to this form of precipitation on the credit side such forms of condensation as dew, mists, etc., and on the debit side evaporation, run-off, absorption or infiltration and transpiration. None of these are constants but vary widely with climatic, geographical, geological and botanical conditions; and as we in this country know to our cost also with the works of man. These variations may be hourly, daily, seasonal or periodic and any attempt to estimate their influence is fraught with many difficulties. It follows from this, that the study of such variations cannot be made in a day or even in a year. Readings and experiments must be made over long periods to ensure anything approaching a real appreciation of their effects. In new countries, such as East Africa, where record making is in its infancy, one is invariably working with insufficient and incomplete data.

The hydrological cycle may be expressed algebraically as under—

$$P + C = R + E + A + T$$

where P is the precipitation, C the condensation, R the total run-off, E the evaporation, A the absorption or infiltration and T the transpiration.

Let us now consider each of these factors.

Precipitation

The main contributor to the earth's store of water is rain. As all who live in the tropics well know, the influence of rain is not merely a function of its intensity or amount. The type of rain, the order of its sequence, the previous climatic history of an area, and the conditions at the time of its precipitation are very important factors in the determination of the ratios of the run-off, absorption, and evaporation. Heavy torrential rain falling on a sun-baked land-surface devoid of vegetation results in exceptional run-off and diminished absorption. On the other hand should such downpours take place in forest areas or grass-covered lands, the run-off is considerably reduced and absorption, evaporation and transpiration are increased. The contour of the land also plays an important part in the deciding of the ratio of these factors, as indeed do the geological conditions.

All rain is due to condensation of moisture in the atmosphere, i.e. the formation of cloud and its subsequent further condensation and precipitation. Condensation is caused by the cooling of the air to a temperature below the dew point, i.e. the saturation point of the air at a given temperature. Such cooling is usually affected by the uplift of the air to higher and cooler altitudes. This uplift may be brought about by either the presence of highlands in the path of the moving streams of air, or by vertical convection due to local heating of the air by hot land-surfaces, or by the meeting of two opposing air-currents.

Hydrologists recognize several types of rain, which are the result of the method or cause of cooling of the air, namely:—

(1) Orographical or regional rains.

(2) Convectional rains:—

- (*a*) Zenithal rains.
- (*b*) Thunderstorms.
- (*c*) Instability rains.

(3) Frontal or pseudo-frontal rains.

(1) *Orographical rains.*—These are due to the chilling of moisture-laden air-currents by the forcing of them to higher altitudes by the highlands in their path. Such rains are invariably seasonal. Precipitation is much greater on the windward side of the highlands than on the leeward, the country to the leeward of the mountains being almost invariably much drier. Such areas in Tanganyika have been named by Gillman "rain shadows", and have played an important part in the water-supply question of that country.

(2) *Convection rains.*—Rains due to this action are of varying types depending upon whether the convection is due to heat of regional or local character or to mechanical disturbances. Vertical convection is brought about in East Africa by the heating of the lower layers of the atmosphere by radiation from the land surface. As would be anticipated, this is more evident when there is little or no wind. The hot air then rises by expansion into the higher altitudes and becomes chilled, precipitating its moisture generally as thunderstorms. These are most common in the late afternoon and are local in their distribution. Thunderstorms are much more common in the tropics than in the temperate zones. "Cloud bursts" are special cases of this character. They are common in areas where there are shut-in valleys surrounded by relatively high hills. In still hot weather the air in the valley becomes heated and absorbs all moisture possible. In the later afternoon this heated air rises and if the rise coincides with the springing up of a local breeze, which carries this heated air against the cool hill-sides, sudden cooling takes place and very heavy downpours result.

Zenithal rains are similarly due to the heating of the air by contact with the land surface. While not coinciding exactly with the times when the sun is at the zenith, they are directly due to this cause. In the tropics between the Tropic of Cancer and the Tropic of Capricorn, the sun crosses the equator twice each year, once on its journey northward in March and again in September on its journey southwards. Rainy seasons follow in the months of April and May and November respectively. Zenithal rains are often accompanied by thunderstorms.

Another cause of convectional rain is the mechanical disturbance set up by local conditions, and affecting the stability of the regular currents. These give rise to what is known as "instability rains". They are common along the coast of East Africa and especially in the relatively dry seasons. For this reason they are the more welcome.

(3) *Frontal or pseudo-frontal rains.*—They are assumed to be caused by the under-cutting of warm damp air currents by colder ones. Such condition can arise when the north-east and south-east trades are in opposition. They are a regional type and are more prevalent in temperate zones, where cyclonic conditions are more common than in tropical areas.

Rainfall Records

From the foregoing it will be recognized that for a real appreciation of the effect of rainfall on water-supply questions, the amount of rain as usually recorded on the charts is not sufficient. So much depends upon the time-distribution and the character of the rain. In new countries such as East Africa rain-recording is in its infancy. Gillman has gone to great lengths to show the inadequacy of the recording stations in Tanganyika. He divides the Territory into 77 degree-squares. No less than 27 of these (35 per cent) have no recording station; 23 degree squares are practically without (30 per cent); and 27 degree squares have 230 recording stations. Many of these latter are in the European settled land and very close together.

The variations of amount of rain are very local, largely due to the geographical relation with the many isolated highland masses. Teale and Gillman quote four adjoining estates near the saddle between Meru and Kilimanjaro. The total area is not more than 11 square miles and the maximum difference of elevation no greater than 300 feet, yet the rainfall figures in one year on these four estates varied between 31 and 39 inches. Lewis quotes the following figures showing the great variation from year to year in East Africa:—

	Maximum	*Minimum*
Mombasa ..	74.3 (1898) ..	22.1 (1922)
Nairobi ..	61.3 ..	22.7
Machakos ..	58.3 ..	21.4

With such wide variations, the importance of records over considerable periods will be appreciated.

Again, another very important factor regarding the precipitation is the distribution of the total rainfall throughout the year. Lewis has arranged a unique chart to illustrate this fact, the monthly rainfall being shown on concentric circles representing mm. of rain and the full circle being divided into the twelve months. Diagram No. 6 is taken from this source. It shows that many places in East Africa have two rainy seasons of widely differing intensity; others have two of almost equal intensity; while a third class have only one rainy season.

In the appraising of any water scheme, it follows that not only is it necessary to study the rainfall figures, but all its characters and variations should be studied in so far as they affect the catchment area.

Condensation

Any one who has walked through the forests or grasslands of East Africa in the early mornings, especially in or just after the rainy seasons, must have been impressed by the amount of moisture deposited by this means. In South Africa careful measurements of such, known as "occult precipitation", have been made on Table Bay and in the Knysna Forest respectively; 9.7 and 11.8 inches was derived from this source per annum. Even in dry areas like the hinterland of Lindi in Tanganyika Territory in the driest period of the year 0.3 inches was collected in one month from this source. When it is remembered that during the prevalence of mists or of dew-deposition evaporation is practically non-existent the beneficial effects of such precipitation must be appreciated.

One school of thought claims that the deposition within the crust of the earth of moisture from the circulating air in rock crevices, fractures, etc., is considerable. That it does take place has been definitely proved by the collection of moisture from this source in sand dunes in desert conditions, but that it is an important factor has yet to be proved. This source is known as "subterranean condensation".

Evaporation

We have examined the credit side of the hydrological cycle. Now we must turn to the debit side. There is considerable difficulty in measuring any of these factors, and it is also impossible to assess the proportion due to each. In some countries and at certain times, run-off is the major factor; in others infiltration becomes all-important; while in arid tropical countries evaporation is probably the most active of these influences.

The difficulty of measuring evaporation losses is enhanced by its widespread occurrence. Losses from this source take place in the atmosphere even before the rain has reached the land surface. How many times has one watched a rain storm in the distance, only to see it disappear in mist before reaching the surface? Such evaporation cannot be measured. The evaporation from the surface of waters, swamps, and from land surfaces varies according to the temperature, the prevalence and strength of the winds, the character of the soil or rock, the types of vegetation, not to mention the time distribution of the rain. In torrential rain much water will run off and be lost to evaporation. During gentle rain absorption and evaporation are increased. The prevalence of rising mists from roads and land surfaces in the tropics after gentle rain is evidence of the activity of this force. Measurement of losses from tanks, lakes, seas, etc., can only be indicative and cannot be taken too literally, as the following annual losses, collected by Gillman on Lake Victoria testify:—

Ukerewe Island 1,540 mm. (60.5 in.); Masaka 1,095 mm. (43 in.); Kampala 1,670 mm. (65.74 in.); Jinja 1,350 mm. (53 in.); Entebbe 1,095 mm. (43 in.); Average 1,350 mm. (53 in.).

On the other hand the Egyptian Hydrological Survey give a loss of 1,166 mm. (43.75 in.) in Lake Victoria and practically identical figures for lakes Edward, George and Albert.

The Public Works Department in Tanganyika have kept records of the losses by evaporation from the reservoir at Dodoma. Of a total of 252 million gallons inflow during the period of test the losses were 186 million gallons or approximately 74 per cent. Some of this was undoubtedly due to percolation losses, but it is estimated that about two-thirds may be taken as due to evaporation. In the Karroo annual losses due to this cause range from 65 to 75 inches. In Southern Rhodesia at the Cleveland Reservoir the loss from this cause over seven years was 90.62 inches per annum. In Bulawayo they were 98.71 inches and in Kitale (Kenya) they are estimated at about 72 inches.

To minimize these losses dams should be as deep as possible, should be protected from winds, and their surfaces covered with the *right* type of vegetation. In West Africa the "water cabbage" has proved an effective protection; in Nyasaland a similar plant known as "water lettuce" is used; and in India the lotus is useful in this connexion.

Certain types of plants, however, transpire so much moisture that the losses from this are greater than those due to straight evaporation.

Run-off

This is of two classes, (*a*) direct run-off, and (*b*) indirect run-off.

The direct run-off is that portion of the precipitation which is immediately carried away in the streams and rivers; whereas the indirect run-off is that portion which having infiltrated into the soil and rocks is returned to the surface as springs and seepages and finds its way into the streams. The total run-off must be considered in any water-supply question. The ratio of the run-off to the loss by evaporation and percolation vary within wide limits, and are controlled by climate, nature of the soil and rocks, the contour of the land and its elevation, and, as we have seen earlier, by the type of rain which has fallen. Further, the immediate preceding history of an area is an important factor. For example in 1919 the Voightsrund Reservoir in South-West Africa is said to have filled with a rainfall of only 19 centimeters; whereas in 1921 with a rainfall of 25 cm. it remained empty. Vegetation and the work of man are also important in connexion with the amount of run-off as this country has learned to its cost. It is estimated that in England about 50 per cent of the rainfall is lost by evaporation; 25 per cent by run-off and 25 per cent by infiltration. In tropical countries, especially those with pronounced and heavy rainy seasons, a very large proportion is lost by run-off. On the other hand in tropical arid countries the run-off dwindles to almost nil, and infiltration accounts for practically the whole of the precipitation.

The following tests carried out in Southern Rhodesia and reported in the Meteorological and Hydrographical Report of 1920 give very interesting information of run-off under African semi-arid conditions:—

Bulawayo Dam.—This has a catchment area of about four square miles, it is steep and the hillsides are covered with grass and bush. The tops of the surrounding hills are bare granite outcrops. The observations were made between 1903–20; the average run-off was 5.07 per cent of the rainfall, which averaged for this period 17.96 inches. The amount of the run-off was proved to be dependent not so much on the intensity of the fall on individual days, as on the degree of saturation of the catchment prior to the fall. Falls of less than one inch per day prior to 1st December produced no run-off, and falls of over one inch per day produced ½–1 per cent run-off in that period. After 1st December a total rainfall of two inches will yield a 1 per cent run-off; of ten inches a 3 per cent; of twenty inches a 5 per cent; and thirty inches a 10 per cent run-off.

Cleveland Dam, situated seven miles east of Salisbury, Southern Rhodesia, has also been carefully tested. The catchment area is about seven square miles. It is slightly sloping mainly covered with sand and vegetation chiefly grass, and comprises granite rocks. The period of examination was from 1913–1920. During this period the annual rainfall was 32.56 inches per annum and the annual run-off 19.83 per cent. Rainfalls of less than half an inch in twenty-four hours prior to 1st December gave no appreciable run-off. The first ten inches of total rain produced about 2 per cent run-off provided it all fell in less than 60 days. Run-off then steadily increased with the rainfall. With a total rainfall of between 10 and 20 inches the run-off increased uniformly from 2–4 per cent, provided there was a fall of two inches every ten days; and for 30–3 inches the percentage run-off increased from 16–25 per cent provided the 38 inches fell in 130 days.

Kanthack in the C.E. of S.A. Journal, 1925, states that with large catchment area, say 1,000 miles in extent, 0.33–0.5 inches rainfall is necessary before any appreciable run-off is noticed.

Examination of six records of catchment areas from 600 to 4,500 square miles in extent, over a period of ten years shows the run-offs varied from 3.2–13.5 per cent in areas with rainfalls ranging from 12.9–29.3 inches. In the Karroo, with an average rainfall of eight inches, the run-off varied from 1.88–5.58 per cent, depending upon the manner in which the rain fell. The Vaal River is estimated to carry between 2–10 per cent of the rainfall in its basin which is about 17,000 square miles. Enough has been quoted to show the importance of protracted and careful readings over long periods.

When we consider the portion of the run-off derived from springs and seepages, our difficulties of estimation are enormously increased. When estimating the surface drainage, given a large-scale well contoured map, and showing the entire catchment area, the major source of error is in the estimation of the percentage run-off. When considering the total run-off, including that from underground sources, we have no reliable data in most cases to work upon. The river drainage areas and the underground-water drainage areas most probably do not coincide. A very carefully prepared and detailed geological map is essential. The structure, history and lithology of the whole area must be known in very great detail; and often these data are not available and not even procurable.

Every stream drainage carries the sum of the surface run-off and the underground seepage. Each stream should be carefully gauged at regular intervals in both dry and rainy seasons, and records compiled over a number of years. Such data are most useful not merely for the purpose of estimating the waters available, but also determining what measures (if any) are necessary for the conservation and protection of such supplies from the ravages of man. Every government should keep careful measurements of rainfall and of the flows of all streams. These records should periodically be examined by competent persons, who would advise the government on the necessary steps it should take to mitigate some of the resultant evils. If such measures were enforced, many of the rivers which are fast passing from perennial to intermittent streams would be protected and their permanence re-established.

Probably the best studied area from a hydrological aspect is the Nile (though the Mississippi has received considerable attention). The Egyptian Government have long employed a scientist to study the sources, the flow, the variations, etc., of the waters of the Nile Basin. They have long realized that the Nile is the life-blood of Egypt. Would that the East African governments had recognized the importance of such studies! The Tanganyika Government have done more than the Kenya Government in this direction. The major trouble is that fear of interference with the native population has often prevented necessary preventive measures being carried out. In my work I have recently come across a whole district, which has almost been converted to a desert through such failure. A study of all data available would appear to show that East Africa is not so much an area of decreasing rainfall, but rather suffering from increased and unhampered run-off, largely due to wanton destruction of vegetation, which in the past has protected the soils.

Absorption

Perhaps a better term for this is "percolation" or "infiltration". In this context it refers to the rainfall or condensed moisture which enters the earth's crust. It is determined mainly by the contour of the land-surface, by the rate of precipitation, the temperature, the character of the soil and the rocks, and the vegetable covering. As the case of the Voightsrund Reservoir quoted on page 201 indicates, a very important factor is the previous climatic history of the area. It reaches a maximum in the case of gently falling rain in relatively flat country consisting of a sandy porous soil or highly fractured rock. In parts of Nigeria it is estimated that 50 per cent of the total rainfall is absorbed. In England this figure is around 25 per cent.

In the next section data are given of the influence of the various rocks on this factor, and the wide variations in absorption properties emphasize the importance of a detailed examination of the geology of the region. Some clays, although impervious, absorb considerable quantities of water, especially at the beginning of the rainy season. This is due to the development of contraction cracks in such clays in the dry season. The fact that absorption is not a direct function of the quantity of rainfall is at last being recognized.

Dixey says:—

"It is remarkable that regions of low rainfall frequently yield better water supplies than those of good rainfall—a result contrary to common belief. This is considered to be due to the fact that in arid regions the rocks are well-exposed and covered only with a thin porous deposit, so that occasional rains can easily penetrate, whereas in regions of higher rainfall the surface rocks are often concealed beneath clayey decomposition products that hinder infiltration of rain-water in the crevices."

Again Du Toit:—

"Infiltration is currently regarded as being roughly proportional to the annual precipitation, but I am inclined to the view that the magnitude of the rainfall is a much overrated factor, except in areas possessing a thick sand cover. Curiously, for example, there has been less trouble in obtaining good yields from hard, close-grained, tilted Karroo beds around Laingsburg, Grootsfontein, and Prince Albert in the Cape—a region with a rainfall of somewhere about five inches—than from the same formation in the Umfolozi settlement in Zululand—one of over thirty inches. We can also compare certain surprising successes in the arid region of the Namib of Namaqualand with distinctly puzzling features in the well-watered territories of Natal and the Transvaal. This paradox arises presumably from the fact that within the semi-arid region the rocks are widely exposed at the surface, or possess a veneer of a relatively porous nature, display cracks that are open and unfilled with clayey matter, are but slightly decomposed and contain pores in which there is hardly any colloidal substances. The occasional rains, therefore are able to penetrate them easily. In the areas of high rainfall the rocks on the contrary are often concealed beneath deep loamy or clayey soils, are usually decomposed in depth and have their crevices filled with amorphous and colloidal matter derived from the extreme weathering of the constituent minerals. Infiltration will thus be hindered, as is also suggested by the high co-efficient of run-off."

In so far as vegetation prevents run-off it assists percolation. The roots provide channels for such infiltration and also break up the rocks and assist the percolation of waters down the resulting cracks. On the other hand the litter of leaves and moss and humus minimize the run-off and also percolation, though facilitating evaporation.

Transpiration

At first sight the losses by these means, which include the transpiration by plants and animals, might appear negligible. Experiments carried out in America, Africa and Australia prove them to be considerable. It is stated that an acre of mature spruce during a growing season in Australia causes a loss of more than 200,000 gallons. Prairie grass in Kansas is estimated to transpire to the extent of 4,500 gallons per acre. An experiment in Austria indicated that in six months growing period a beechwood forest transpired the equivalent of 22 inches of water. Contrary to the general belief, an extensive series of experiments would appear to indicate that the desert plants transpire moisture at a greater rate than rain-forest plants.

Transpiration can only commence after absorption has taken place. It is obvious that such transpiration must decrease the available groundwater supply. Our knowledge on this subject is very deficient. The measurement of transpiration is difficult. It changes from hour to hour, from day to night, from season to season, and also with the type of vegetation. As a consequence the differences of opinion as to the importance of this factor are amazing. Some aver that forests rather than conserving water supplies dissipate them, by their action in draining the soil, as well as by transpiration from their leaves. On the other hand, others insist that they are an important factor for increasing supplies, by decreasing run-off, as well as by the chilling of the atmosphere by evaporation from the foliage and thus assisting precipitation. It is clear that the effect of forest on water supply depends on the character of the soil, the nature of the rainfall, the contour of the land and the types of trees. There is no doubt that certain types give rise to considerable transpiration losses. In Uganda gum trees have been used extensively for drying up swamps. Researches in South Africa show that black wattle, fast-growing gums and exotic pines exert a great desiccating influence on the soil. In the forest of the Landes, the extensive clearings in the 1914–18 war resulted in a marked rise of the water table, and in some cases produced swamps.

GEOLOGY AND WATER SUPPLY

Since underground water is largely dependent upon the infiltration of rain-water into soil and rocks, and since springs largely control the escape of such ground-waters, it is essential that we should study—

(1) the various absorbent properties of rocks, i.e. lithology;

(2) the reasons for the location of these springs, which are dependent on (*a*) stratigraphy, i.e. the relations of the rock formations, (*b*) tectonics, i.e. the structure of the rocks and their deformation, etc.

TYPES OF SPRINGS

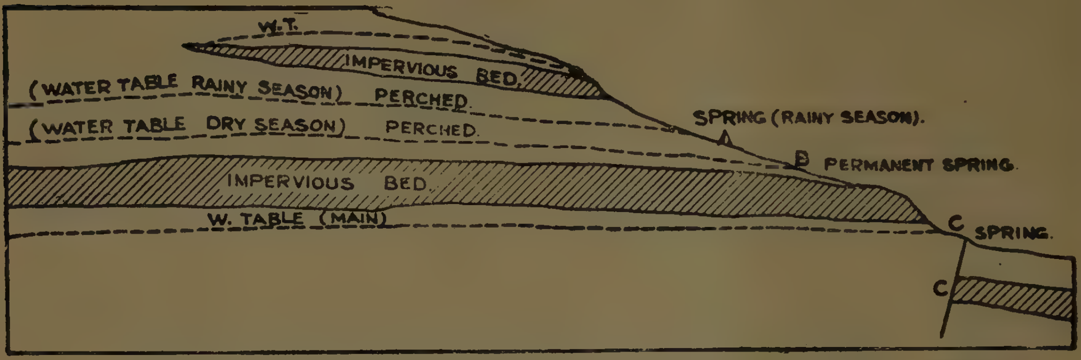


Diagram No. 1a.—Showing oscillation of water table, perched water table, springs, spring due to presence of a fault.

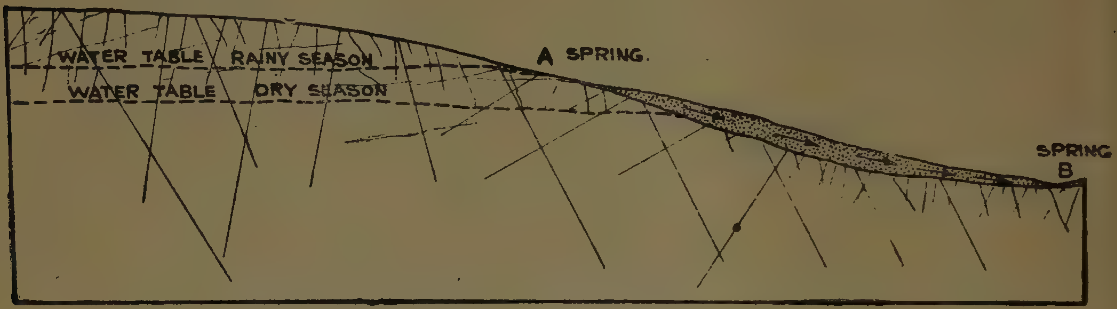


Diagram No. 1b.—Showing springs in fractured rocks, with oscillation of water table. Permanent spring "B" from overlying sands.

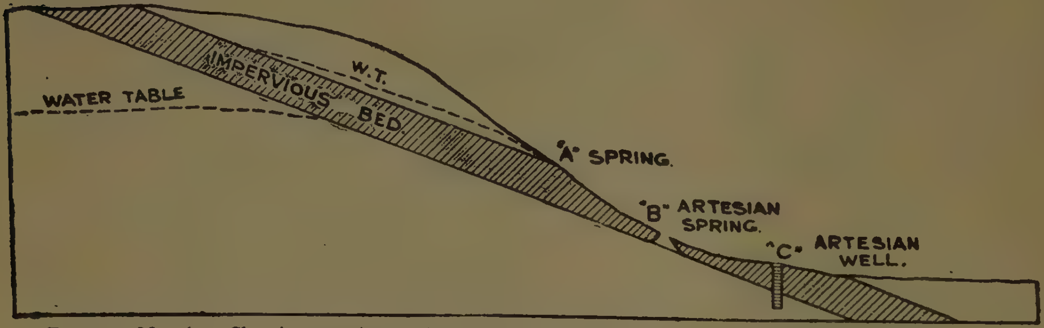
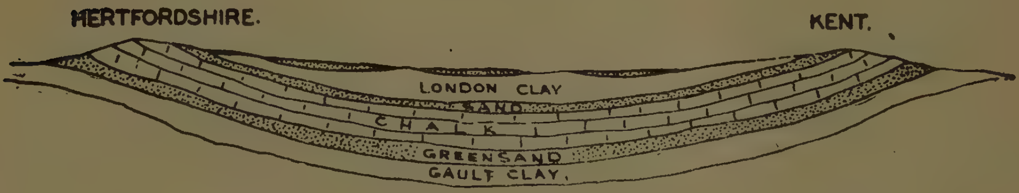


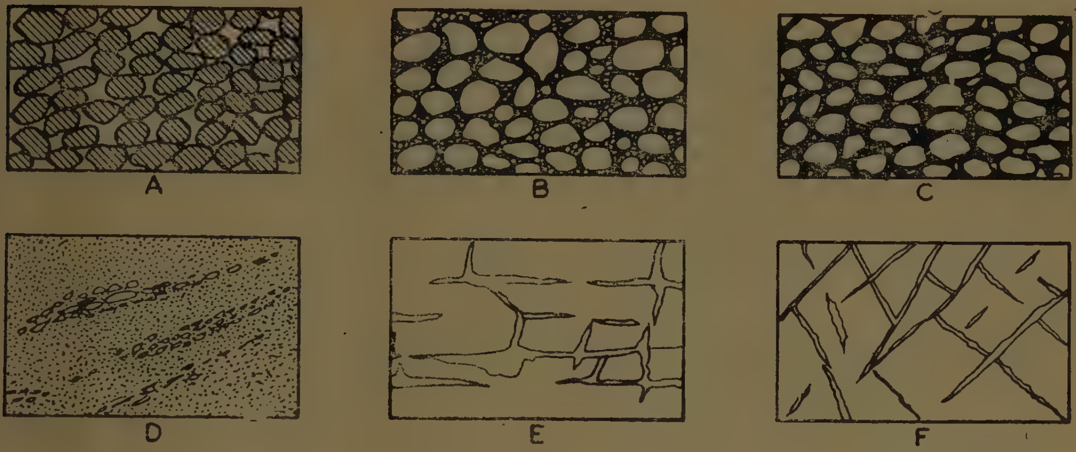
Diagram No. 1c.—Showing artesian well and spring "C" and "B" and "A" intermittent spring.

LONDON BASIN



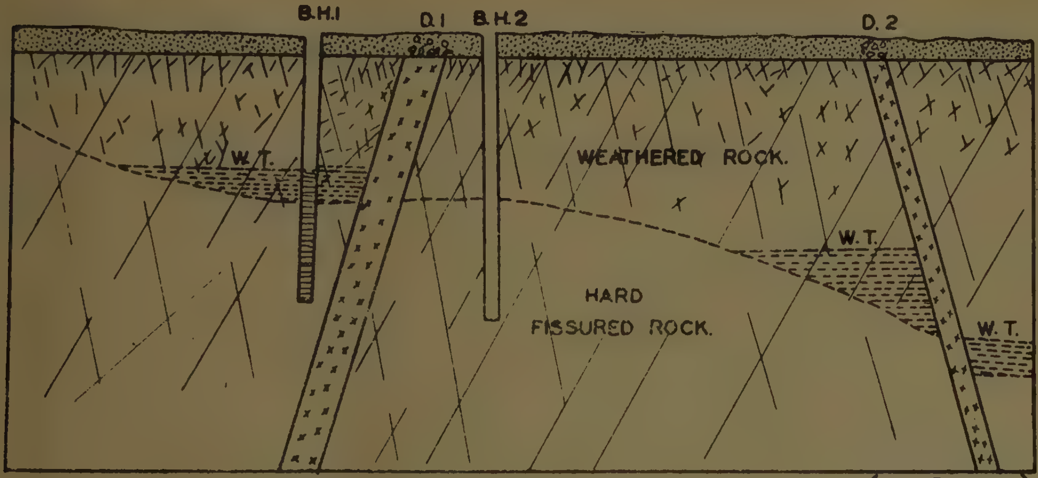
(After Shand)

Diagram No. 2.—Showing the artesian basin underlying London. Water is held in the chalk and upper greensand between the impervious London clay and the Gault clay.



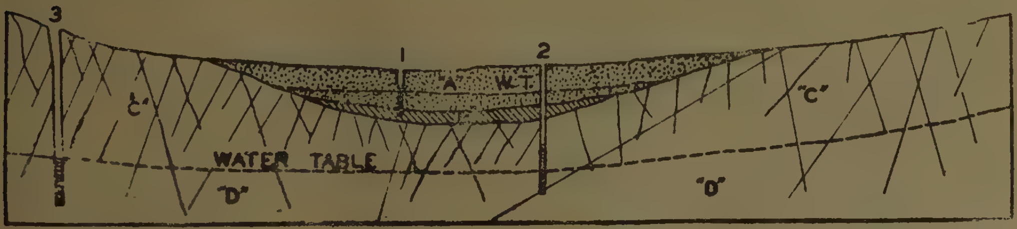
(After Meinzer)

Diagram No. 3.—Showing relation of rock texture and porosity. A.—Well-sorted deposit of high porosity. B.—Poorly sorted deposit with much interstitial matter resulting in low porosity. C.—Well-sorted deposit, porosity decreased by mineral deposition in interstices. D.—Variable deposit with lenses of gravels and clays in fine sands, resulting in variable degrees of porosity. E.—Cavernous limestone rendered porous by solution along jointing and bedding planes. F.—Rock rendered porous by fracturing.



(AFTER DIXEY)

Diagram No. 4.—Showing the impounding effect of intrusive dykes on groundwater. B.H.1 struck water impounded by D.I. Dyke. B.H.2 was dry being unaffected by the dyke.



(After Dixey)

Diagram No. 5.—Showing position of perched and main water-table: Well No. 1 is in the perched water-table; Nos. 2 and 3 in the main; "A" is water-yielding strata; "B" is impervious bed; "C" dry fractured zone; "D" saturated fractured zone.

DISTRIBUTION OF RAINFALL

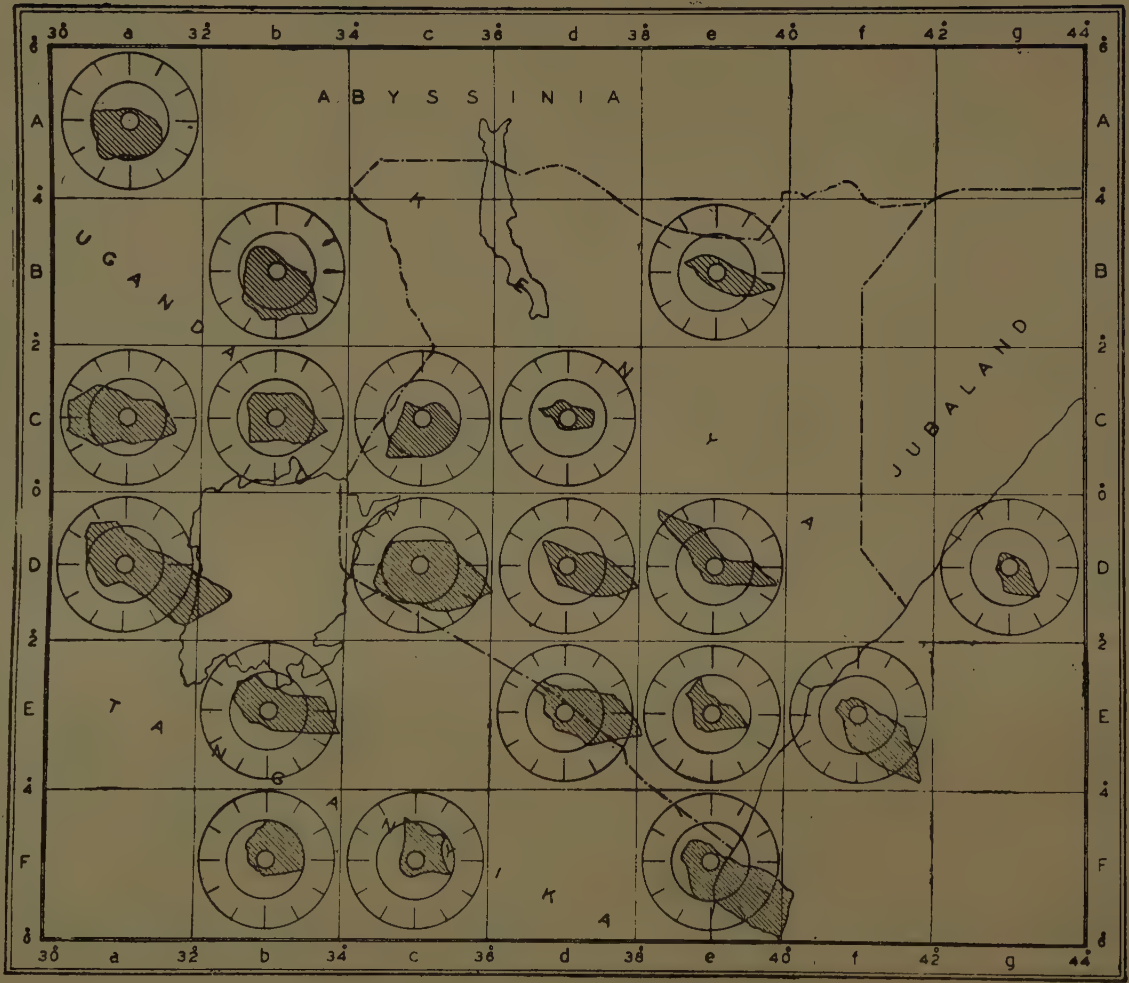
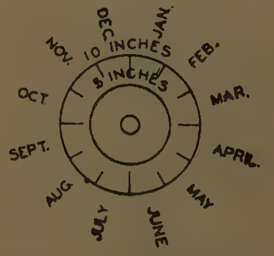


DIAGRAM NO. 6

INDEX

SQUARE	BASED ON
A a	MONGALLA
B b	KITGUM
B e	MOYALE
C a	FORT PORTAL
C b	JINJA
C c	ELDORET
C d	ARCHER'S POST
D a	BUKOBA
D c	KERICHO
D d	NAIROBI
D e	KITUI
D g	KISMAYU
E b	MWANZA
E d	ARUSHA
E e	VOI
E f	MALINDI
F b	TABORA
F c	KONDOA IRINGA
F e	SHIMONI

KEY TO DIAGRAM.



(After Lewis)

Lithology

From a water-supply point of view, rocks may be classified as (*a*) permeable, or (*b*) non-permeable. Perhaps a better classification is as (i) waterbearing or yielding rocks, i.e. aquifers, (ii) non-water bearing or yielding rocks. Water-bearing rocks again fall into two groups, (*a*) porous rocks, i.e. rocks which hold water in interstices throughout their mass, (*b*) impervious rocks (but holding water in joint planesbedding, cleavage and foliation planes and in fissures and fractures).

A rock is said to be saturated when all the interstices and/or fractures are filled with water. The upper surface of the zone of saturation is known as the "water table". All pervious rocks below the water table are saturated. Not all the water even in a saturated rock is "available water", and the value of a rock as a source of water depends more on its specific yield than on its porosity. Many clay formations may contain large quantities of water, but as water yielders they are useless. Sands, uncemented sandstones and conglomerates may contain much less water, but will yield that water more abundantly. In granular rocks, e.g. sands, sandstones, conglomerates and gravels, the water is held in the interstices between the grains (*see* Diagram No. 3). Where these are cemented, as in quartzites, indurated sandstones, etc., their water capacity is considerably reduced, and may be nil. Granular rocks composed of large or small grains of uniform size are highly porous, while those consisting of grains of mixed sizes are considerably less porous, due to the reduced percentage of interstitial spaces. Limestones and such relatively soluble rocks, though originally non-porous, may become excellent water-bearers due to the development of caverns and opening of joint planes. It frequently happens that rocks such as granites, gneisses and schists become very porous to depths of a few hundred feet, due to weathering of ingredients in the rock and to the opening up by such action of fissures and joint planes. The nature of the weathering decides the degree to which they become water-yielding. If such processes of decomposition give rise to clayey or colloidal matter the water capacity even of the weathered rock is not materially increased.

One cubic foot of coarse sand will absorb 2.10–3.0 gallons, one of fine sand 1.8–2.10, one of sandstone 0.5–1.37, and one of limestone 0.12–0.54 gallons.

Du Toit states:—

"In the case of the flat-lying dolomites near the Rand with its sand covering, absorption is equivalent to about 11.7 per cent of the rainfall."

Beeby Thompson, writing on Kenya water problems, states:—

"The earth itself constitutes by far the best container for water, which as a rule undergoes purification in its descent and travel through rocks, where it is preserved from pollution and evaporation losses until abstracted for use. Crystalline rocks which cover the bulk of Kenya are not good water-yielding beds, for neither the volcanics, metamorphic nor igneous types are themselves porous and permeable, but fortunately they are subsequently fissured and decomposed at many points to cause them to admit and to hold water, and in this way to behave much as permeable sedimentary rocks."

Again Dixey remarks:—

"Almost universally there is a tendency for the gneissose and banded types (of metamorphic rocks) to weather along the planes of foliation, and to acquire a most valuable fissile character, but occasionally even the homogeneous granite is friable to considerable depths, largely as a result of the partial kaolinization of the felspar crystals. Nevertheless, in most cases the water appears to be stored up in the crevices and joints rather than in such porous parts of the rocks, it being remarkable to find the sound formation traversed by such joints at distances in some cases of over 300 feet beneath the surface. Three peculiarities excite some surprise:—

(1) The depths to which it may be necessary to go for water.

(2) The excellent supplies so commonly obtained in these compact plutonic rocks.

(3) The good yields to be obtained upon rising ground in certain areas."

It must be remembered that, as greater depths in the earth's crust are reached, the joint planes, cracks, crevices, etc., are closed by the great pressures. Deep mining has proved that water is rarely found below 3,000–4,000 feet depth in such crystalline rocks. (*See* Diagram No. 4.)

The percolation of water through the rocks is controlled by the force of gravity; capillarity merely acting as a delaying influence, no matter whether the percolation is in a vertical or lateral sense. This force of gravity is active in the supply to all springs, wells, and boreholes. The flow depends upon the size of the interstices and fissures and the percentage of clayey or colloidal matter dispersed through these. Where a rock is "tight", that is the interstices are small or are almost filled with cementing material or clayey matter, the flow through these rocks is slow. This factor is also influenced by the relative position of the spring, well or borehole to the water table. After some years of operation wells frequently give very decreased yields. This is often due to the flow of water to the well carrying colloidal and clayey matter with it and closing the interstices in the surrounding strata. This is why it is always advisable to draw from a well or borehole considerably less than its capacity.

Stratigraphy

Equally with a knowledge of the lithology it is important to know the structure of the rocks, and especially the relations between the water and non-water-yielding beds. One of the world's classic examples of geological structure in relation to water supply is that of the London Basin (Diagram No. 2). The underground water supply of the London area is derived from the chalk and the underlying greensands. The upper beds are largely composed of clays (London Clay), which are impervious, but rain falling on the chalk hills of Hertfordshire, and the North Downs, percolates through the joint planes, pipes and crevices in the chalk and drains into the synclinal basin. When this reservoir was first tapped, the wells were artesian; i.e. the waters rose above the ground level. Now with the excessive drawing on this supply, the level has been reduced by some 100–200 feet. When the wells in Trafalgar Square were sunk, the water rose in the fountains in the square. Now the water level is about 100 feet below the ground level. It is estimated that the water drawn from underground sources underlying London is about three and a half million gallons per day.

Diagram No. 4 shows the influence of igneous dykes on underground water supplies. Usually such rocks are impervious and prevent the lateral migration of the underground waters. Where such a rock cuts through the junction of pervious and impervious beds, at this point there will be an accumulation of underground water and such a structure may very likely give rise to artesian conditions. In the case of a batholithic intrusion, the subterranean shape of such mass must be determined in order to ensure the location of underground water bodies. In his studies of the hydrological zones in Tanganyika, Mr. Gillman recognizes the importance of a knowledge of geological stratigraphy. He writes:—

"A second type (Ib) is found on ground that receives less rainfall (between 800–1,200 mm. only) and where permanence of springs and stream flow is obviously the *result of favourable gealogical formations,* in the shape of paleozoic and mesozoic non-metamorphosed strata."

Structure and Tectonics

Geological structure and the tectonic history of an area is no less important than lithology and stratigraphy. Unless one can prognosticate the lie of the various strata at depth, it is impossible to locate and appraise any underground body of water. In the diagram No. 2 of the London Basin, the synclinal structure is of equal, if not greater importance, than the alternations of water- and non-water-yielding strata. The run of faults, the intensity of folding, etc., must be known, before one can give an idea of the water possibilities of an area. Gillman recognises this when he writes:—

"In addition to the dominating influence of tectonic structure on the evolution of the East African river systems, the influence of climate plays an important part. . . . As a consequence of the tectonic dismemberment resulting in frequent and sudden high to low, from full exposure to the rain-bringing air-currents to deepest rain-shadow conditions, very different climate types dovetail into each other in such a manner that a major river frequently changes from one type to another."

Again he writes:—

"Older features of the earth's surface, expressed by more or less far advanced denudation, have recently been distorted along well pronounced tectonic belts by differential movements of the crust. . . . By this shattering, more than probably repeated several times during Mesozoic and Tertiary times, pre-existing drainage patterns have been rudely disturbed."

Recently I have studied a water problem in Tanganyika. Until 1939 the river Ngerengere had never been known to run dry. It was a perennial stream. In that year and subsequently in the dry season the flow has disappeared or dwindled to negligible amounts. As this was the source of the water with which I was mainly concerned, it was necessary to delve deeply into the probable reasons for such failure. This study showed how by the excessive run-off from the Uluguru Mountains, due to the cultivation of the mountain slopes, and the removal of the protective vegetation, the protective silts and muds in the Ngerengere River had been scoured out. This river bed is crossed by an important geological fault known by the Tanganyika Geological Survey as the Ngerengere Fault. The removal of the silts from the portion of the bed of the stream crossed by this fault has increased the percolation of water in this fracture. Hence this hitherto perennial stream has become intermittent. Without a knowledge of the presence of this fault, the reason for this would not have been found.

WATER TABLE

In a preceding section (*Lithology*) we have seen that the water table is the upper surface of the zone of saturation. In order to foretell the permanency of water supplies from wells or boreholes, it is essential to study the water table closely. We can only speak of a water table or a zone of saturation in the case of a water-yielding strata. Such level is not stationary, but fluctuates with the rainfall, the varying degrees of infiltration, etc. It is possible to have in one locality two water tables due to alternations of permeable and non-pervious beds. The upper one in such case is termed a "perched water-table" (*see* Diagrams 1A and 5). When a spring ceases to flow or a well ceases to yield water, it generally means that the water table has been lowered, and the location of the spring or the well is above the upper surface of the zone of saturation. It frequently happens that the water in a swampy valley is of the nature of a perched water table; this also explains why many wells sunk on the margins of such swamps, prove failures. Similarly it explains how a borehole after giving low yields at relatively shallow depths passes into an unproductive zone. The upper surface of the zone of saturation is rarely horizontal, but it rises with the contour but usually less sharply than the contour. Consequently the depth at which water is struck in a well sunk on the divide between two streams, provided this divide is composed of rocks in the zone of saturation will be less than the depth of the river valley below such point. In water-bearing strata the depth of the water table below the surface is very variable, depending as it does on topography, geology and climate. Differences in the nature of the soil and in the type of vegetation also influence this depth (cf. section on "Absorption").

Generally speaking the porosity of a rock decreases with depth. Fissures and fractures also tend to disappear at great depth. Deep mining has proved that generally water decreases in volume below 3,000–4,000 feet. In every instance, however, before any idea of the lower limit of the zone of saturation can be gauged, extensive researches must be conducted. In some localities undoubtedly water does find access to the heated portions of the earth's crust (*see* section on "Classification").

PHYSIOGRAPHY

The study of physiography is equally essential to an understanding of the distribution of water both on and under the surface of the earth. Altitude, contour, character of drainage all play an important part in the collection and storage of water. Especially is this so in a country like East Africa. All here know of the general distribution of the rain belts with reference to the highlands. The hills of the coastal belt rising 1,000–1,500 feet above sea level intercept a considerable quantity of the moisture borne by the air currents from the Indian Ocean. The relatively flat lands of the "Nyika" from 40–50 miles inland to the rise of the highlands heat up these currents by convection. Consequently instead of precipitating further rains they dry up the country and give rise to semi-desert conditions. This type of country stretches throughout Kenya and southwards into Tanganyika. Wherever on this plateau isolated hills (Inselbergs) stand out one finds areas of heavier rainfall, e.g. the Teita, Chyulu, Usambara, Uluguru and Mahenge Mountains, and further inland the Yatta Plateau and the Mua Hills in Kenya and the Iringa Mountains of Tanganyika. The smaller these inselbergs, the less their effect. Still further inland we find the Highlands with their heavier rainfall. Still further west, the great freshwater lakes of Tanganyika and Victoria give rise to special local rainfall distribution, which can only be explained by a first-hand knowledge of the principles of physiography.

In East Africa large areas consist of volcanic rocks which have been extruded on to an ancient land surface consisting of gneissic rocks. This old land surface was deeply eroded before the deposition of the volcanic lavas and tuffs. An intricate river system had been developed thereon. It is well known that water is invariably found at the contact of the volcanic beds and the gneissic floor. The amount of such water very largely depends upon the location of the well or borehole with regard to the contour of the gneissic floor. If it coincides with an old drainage channel, invariably the quantity is considerable; if such channel should chance to be that of a large river-bed the amount may be prodigious. It is important therefore to seek every means of tracing the courses of the now blanketed stream or river systems in any attempt to find water under the volcanic beds. At Mitubiri a farmer wanted clean water to wash his coffee, and proposed sinking a borehole on the edge of a swamp running through his farm. Fortunately he was persuaded to sink a borehole on the highest point of his land, from whence he could gravitate it to his factory, dairy and houses. He found all the water he wanted. Again in the Tana River evidence was secured which proves that the present river bed has no relation whatsoever to those which originally drained the old gneissic floor in this area.

SOURCES OF WATER SUPPLY

Man has had recourse for his supplies of water to (*a*) rivers and streams, (*b*) springs, (*c*) wells, (*d*) boreholes.

(*a*) *Rivers and streams.*—The winning of supplies from rivers and streams is entirely an engineering proposition either for the mechanical engineer in the provision of pumps and mechanical power to raise the water; or for the civil engineer in the provision of storage, spillway, and the protection works and pipe-lines. The geologist can be of service in the location of the reservoir site where conservation works are contemplated. His business is to advise as to the soundness of the beds comprising the floor of the reservoir, the freedom from pervious beds and zones of fracture, and the soundness of the strata upon which the dam is to be constructed. At a recent conference held in Nairobi, the question of water conservation was considered. The Tennessee Valley Scheme was cited, and the opinion voiced that East Africa needed such a project. Two technical men present at the Conference did not fail to point out the impossibility of such scale operations in East Africa. In 1925 Lewis emphasized that the possibilities for irrigation, i.e. for large water conservation schemes, were not very extensive. He wrote:—

"Nor can this area (i.e. the area that could probably be irrigated) be increased very much by means of storage, for the bulk of the country is too steep for the construction of economic storage dams."

Small dams can undoubtedly be constructed to good effect throughout the country, and they would be invaluable in (to use President Roosevelt's words) "retarding the journey of the raindrop to the sea". They would also raise the level of the water-table throughout wide areas; increase transpiration and humidity of the atmosphere, and doubtless further influence precipitation. I have in mind cases of dams in the Kiambu and Kitale areas, which have resulted in making intermittent streams perennial, and in considerably improving crops in their vicinity.

(*b*) *Springs.*—Ground water often finds its way to the surface by means of springs and seepages. Dixey classified them into gravity springs, artesian springs, and those associated with deep-seated factors. Frequently these latter type are mineral-bearing and hot springs. Such waters are almost undoubtedly of juvenile or plutonic origin. The diagrams Nos. 1A, B and C indicate the formation of gravity springs. They invariably arise at the junction of permeable and impervious beds. The latter arrests the downward flow of the underground waters. Wherever the contour of the country brings the surface below such contact, provided the permeable beds are saturated, springs will develop. Seepages are merely springs where for some reason or other the flow is limited or widespread in its escape to the surface. They are due to the same causes. Frequently springs and seepages mark lines of fractures. When these are filled with clayey matter they are often impervious but somewhere along the line of fracture they bring pervious beds to the surface. Often around seepages a yellowish floating scum is found. This to the uninitiated is often regarded as a sign of mineral oil. It is merely due to iron compounds from the soil and rocks, and the action of decomposing vegetable matter.

It is sometimes possible to increase the flow of a spring, but any attempt to do so must be in the nature of a gamble. If the impervious layer, which has given rise to the spring be thin and it is penetrated, then the entire water supply may be lost. In the course of time, springs often change their horizon. I know of one case where a spring had for a decade or more issued from a cliff of laterite. This spring gradually failed. The owner falsely blamed the local natives for this, accusing them of tampering with it. What had happened was that the spring water had carried to the surface the fine clayey matter in the interstices of the laterite, and its removal over a number of years had rendered permeable the hitherto impermeable lower layers of laterite. Consequently the spring emerged at a lower horizon. Springs may often be located by the superficial accumulation of tufaceous deposits, ironstone deposits and other mineral accumulations.

Artesian springs are so-called as they were first recorded in the Artois Province in France. The waters of such springs issue at the surface and sometimes to considerable heights above the surface. Diagrams Nos. 1C and 5 indicate their cause. It is a similar action to that of water in a U tube. The resistance to the flow of water in the permeable strata must be allowed for. Earlier it has been mentioned that the wells in Trafalgar Square, London, were originally artesian. Artesian wells are due entirely to the geological conditions, and they have little or no relation to contours, other than the surface at which the strata gets its water by percolation must be at a higher altitude than the location of the well. It is possible to have artesian conditions in crystalline rocks. Diagram No. 5 indicates the essential conditions. I understand that an artesian well has recently been struck in the Lumbwa District.

(*c*) *Wells.*—In this paper wells are regarded as excavated shallow holes in the ground, and usually of three or more feet in diameter; as distinct from boreholes, which are of small diameter, say up to twelve inches and sunk by some cutting tools either raised and lowered or rotated. Wells have the advantage over boreholes that they require little capital. As compared with springs they are not so prone to pollution and the supply from wells is more easily delivered to pumps. Any well sunk into a saturated pervious bed will yield water. Occasionally it will be found that a well has ceased to yield water. This is usually either due to the water table falling below the bottom of the well, or it may be due to excessive drawing from the well and to clayey matter sealing the interstices in the pervious strata surrounding the well. This latter is not so common in the case of wells as it is with boreholes. The probable yield of a well is very difficult to estimate. Shallow wells are generally much more inconstant than deep ones. If the beds, from which the well is drawing water, are fine-grained and yield their water slowly, a wide-diameter well is desirable. Some wells have been sunk to considerable depths, one or two hundred feet, and to increase the yield collecting galleries have been driven into the wall rock. This was a common practice in the early days under the London Basin.

(*d*) *Boreholes.*—Generally speaking, boreholes have greater yields than wells, primarily due to the fact that they penetrate greater thicknesses of water-yielding beds. It is not proposed to deal here with the types of boreholes and the methods of their sinking. In the matter of the location of a borehole, it is essential to have the maximum data possible on the geological character and disposition of the strata to be penetrated; and the geological structure of the surrounding country. The presence of an undetected fault or of a dyke intrusion may upset all one's calculations and the result be entirely different from that expected. It is generally found that when water is encountered in a borehole, it rises in the borehole to a higher level than that at which it was reached. This is known as the "static level", and care should be taken to record both the depth at which water was struck and the height to which it rises. This rise is due to the hydraulic pressure of the water in the water-yielding bed. The pressure being released in the region of the borehole the water rises. This level may be subject to considerable fluctuations. Some of these are undoubtedly seasonal and follow, often after some time, the rainy periods. It takes an appreciable time after rainfall to transmit water to the borehole and raise the water level. The fluctuations of the water-table are greater away from ravines and scarps. Though the water-table may rise several feet, the increase in the general slope of this to the spring at the surface is altered but slightly.

The following quotation from Du Toit is of interest in connexion with the yield boreholes in the gneissic formations of Africa:—

"That a decomposed friable formation should produce by means of a borehole from 5,000 to 25,000 gallons per day, seems not unreasonable, but that an apparently solid plutonic rock so compact that the cores thereof may have to be broken off for their extraction, should furnish, and that continuously, equally large volumes is indeed astonishing. In difficult formations and situations a few hundred gallons in 24 hours may be all that can be obtained—merely enough for domestic purposes, but in good country from 40,000–70,000 is not uncommon. Tested yields of over 100,000 gallons per diem are rare and usually imply special geological conditions, such as a dolomite or a quasi-artesian source."

Geophysical Aids

This paper would not be complete without some reference to the application of geophysical work to water finding. Recently a paper was read before the Geological Society of London by Major Paver on "The application of the electrical resistivity method of geophysical surveying to the location of underground water, with examples from the Middle East". I cannot do better than quote extensively from that:—

"It has, of course, long been accepted that advice as to the procuring of water from subsurface sources is a geologist's function, and in most countries government-sponsored schemes for the development and production of underground water supplies, if not always coming directly under the control of geologists, are at least able to draw freely upon geological advice. . . . In recent years geophysics has been called in more and more as an aid to the geologist in water supply problems. This may be attributed partly to the advances made in that science, partly to an increasing realization of the importance of water supply, and partly to the increasing complications inherent in the fact that not only is it the drier areas which remain for new development but also that in areas already developed increasing quantities of water are ever being demanded. Geophysical methods, as do geological, locate water indirectly; and just as the estimation of the depth, amount and quality of water available is one of the most difficult questions to confront the practical geologist, so the interpretation of geophysical results in terms of hydrological data is one of the more difficult problems of applied geophysics and necessitates particularly intimate knowledge of geology.

The four major branches of geophysics (seismic, gravimetric, magnetometric and electrical) all have their possible application to underground water problems. The seismic and gravimetric methods, however, are both scientifically and economically suited only to large-scale problems, where major geological structure control the underground water conditions of a whole region. . . . Magnometric measurements, the quickest and least expensive of all geophysical methods, have been extensively employed to locate igneous intrusions such as dykes and sills, and some strikingly successful results have been obtained by this very indirect application of the magnetic method to the location of boreholes for water. The electrical resistivity method is by far the most extensively employed in the problem of locating underground water supplies. This is largely for the technical reasons that it most nearly approaches the ideal direct location of water and yields information concerning the changes of strata in depth, and also for the practical consideration that it is comparatively quick and economical. . . . In this method the particular physical property which is measured is rock resistivity. The resistivity of a material is a specific property and varies considerably with the various rock types; it also depends upon the actual moisture content of the rock formation, and in saturated formations upon the mineral content of the water present. . . . Interpretation of the significance of an electrical probe curve can be attempted by mathematical or physical analysis. It may also be attempted empirically. It is in the translation of this data into hydrological information that the need for geological knowledge arises. A purely mathematical-physical analysis seldom yields a solution, and is insufficient without the knowledge of the probable, or possible, geological conditions and structure, which in turn must be converted into information concerning the underground water conditions at the site. . . . Speed of operation is such that resistivity surveying can easily keep ahead of the drilling programme, and the cost is only a fraction of actual boring. In a normal working day ten electrical depth probes to a depth of 300 feet can be observed."

Some years ago, a geophysical survey was carried out in the coastal area of Kenya under my direction. This was done for the purpose of locating beds of coal believed to underlie the surface grits. Two methods of geophysical surveying were adopted; one, electrical, consisting of earthing a current and measuring and mapping lines of equi-potential between two poles; the other was gravimetric and was carried out by the use of the torsion balance. Certain results were obtained and mapped. The geophysicists were absolutely at a loss to interpret these results in terms either of underground geological sequence or structure. A detailed geological map of the area geophysically examined was prepared. A careful study of the geophysical data in light of the geological conditions led to the conclusion that the differences in electrical conductivity and of specific gravities disclosed by the geophysical surveys were due not to geological strata and structure but to the occurrence of water in the joint planes in the grits. These differences had entirely masked any differences due to geological factors, and consequently from the point of view of the purpose for which it had been undertaken, the geophysical surveys were a failure. The importance of an intimate co-ordination of the geophysical and the geological work is thus further emphasized.

In order to stress the wide applications recently made of geophysical surveys in connexion with water finding I cannot do better than to give the list prepared by Major Paver in his paper above mentioned:—

"The application of the resistivity method to the complex problem of underground water supplies is outlined by examples from Egypt (Western Desert, Delta Area, South-eastern Desert), Sinai (including parts of Palestine, Trans-Jordan, and Egypt), Palestine, Trans-Jordan, Syria and Cyprus.

These examples include resistivity surveys directed towards—

(1) the location of main water tables in homogeneously porous deposits;
(2) the location of perched water tables in folded limestone formations;
(3) the location of areas of deepest deposition of porous alluvial deposits in drainage channels;
(4) the differentiation and delineation of more porous arenaceous beds and less porous argillaceous beds in alluvials, deltaic deposits and recent Pleistocene and Pliocene formations;
(5) delineation of limestone/marl variations;
(6) measurement of depths and state of decomposition in areas of homogeneous crystalline rocks;
(7) location of presence of interbedded porous flows in lava areas;
(8) location of sub-surface water-bearing formations under cover of more recent beds;
(9) location of formational geological contacts in depth.
(10) delineation of igneous intrusions;
(11) qualitative estimates of salinity;
(12) qualitative estimate of yield."

Dowsing

This is also known as "water divining" and is the art of locating water by means of the movement of a twig or other instrument. Every text book or geological work decries this and expresses lack of belief in its usefulness. Certainly one cannot see what (if any) scientific principle is involved, and for that reason one greets its use with scepticism. Further one hears a lot of persons who have the gift of divining for water, but when a real necessity arises often the very people who are credited with such powers do not apply it.

Lewis writing on the water problems of Kenya states:—

"In no part of the world, have I found such universal faith in the water diviner or dowser as in Kenya. I have no faith whatsoever in the possibility of locating underground water supplies by means of a divining rod."

An extensive review of the practice and of its publications was made some years ago by Professor Gregory. The result of his examination was that the movements of twigs, etc., were either—

(*a*) conscious movements used as fraud or as a practical joke;
(*b*) unconscious imposture usually associated with personal egotism;
(*c*) unconscious movement induced by some intuitive impulse or local knowledge.

My own opinion is that this finding is unkind, to say the least, and I am sure it is not the whole truth.

Until a few years ago I was very sceptical of any possibility of movement of a twig, whether by underground water or other causes. Now I know by personal experience that with some persons movements are imparted to a twig by some hiatus or fracture in the rocks, but whether or not this is due to water in the fracture or to the fracture itself I cannot say. I know of one quartz reef that was mapped by the twig. Subsequent work showed a most remarkable correctness of the map prepared by divining. In a mine that I was associated with, a fellow geologist was taken over the surface with a twig. He got movement at certain points, and in every case those points were above places where by underground work we had proved the occurrence of fractures. I tested this out and got similar results. The visiting geologist could have no indication from the surface of the points to make his twig dip, if one claims that it is consciously or subconsciously done. If every other aid failed I might be tempted to use the twig. I must confess that I am not convinced that it might be unwittingly dipped by the operator, at points where for some reason either his local knowledge or some bias makes him wish it to dip. If such is the case I emphasize again that it is unwittingly and there is no desire to fraud or even to deceive oneself. I know this is contrary to all scientists' views, but I must report my own experiences.

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(The discussion that followed Dr. Parsons' address is of such interest that it will be printed in full in the next number of the Journal.—Ed.)

AGRICULTURAL EXTENSION METHODS AMONGST AFRICAN PEASANT FARMERS

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It is notorious in many countries that it is easier to devise improved agricultural methods than to get them put into practice by the mass of the farming community. Departments of Agriculture are normally divided between these two functions, i.e. into a research side and an extension side, of which the latter usually absorbs much the larger staff. Research work is so directed as to be always a few jumps ahead of the methods in current use, but its potential must always be limited by the fact that too many improvements cannot be "put across" at once within the limits of expenditure and staff available for the extension side. If, therefore, extension techniques can be improved, a given amount of staff could accomplish more work and research could also go ahead faster, to the general betterment of agriculture.

In the past far too little attention has been paid to the technique of extension work, although in Africa the results obtained to date are frankly disappointing. In British colonial territories courses are held to train agricultural officers, instructors, demonstrators and the like, at which a practical knowledge of agriculture is instilled, but it is rare indeed for a lecture to be included in which the student is taught how he may best "put across" his knowledge to practical farmers. Extension work has a technique all its own in which there is much to be learnt from experts in psychology, advertising, journalism, broadcasting, films and other forms of publicity. The Ministry of Information in Britain and the information offices which have been set up in many British colonies during the war have acquired much experience in this subject. It is time that extension work should be regarded as a separate sub-science of agronomy requiring special study, and in some larger territories perhaps needing specialized staff for supervision.

The matter contained in this paper is derived from my own experience in the Uganda Department of Agriculture, but any views expressed are to be taken as personal and not necessarily as part of the official policy of the Department. It is proposed to deal with the subject under three heads, namely: extension work by personal contact, publicity methods, and principles which appear to arise out of present experience.

PERSONAL CONTACTS

In British territories the usual set-up for district extension work consists of a grade such as district agricultural officer, with a junior staff of instructors, demonstrators, or some similar title. For the sake of brevity in the following paragraphs, these grades will be referred to respectively as the "officer" and the "instructor." (In some cases there are intermediate grades, either European or African, but this does not affect the sequence of the argument.)

The officer is a comparatively highly-paid European official of whom the territory obviously cannot afford many; and results commensurate with the salary he receives are expected, i.e. that his expert knowledge should be diffused to as large a number of farmers as possible. Generally speaking, he should therefore when on tour not waste his time in lengthy discussions with one or two farmers at a time, but should arrange to meet groups such as local native councils, co-operative societies and the like who can provide large audiences which justify some time being spent on them, either in talk or demonstrations.

This rule is, however, subject to two main exceptions. Firstly, the officer must allot a small proportion of his time to visiting individual cultivators on their farms in order to retain his practical outlook, i.e. to observe the average standard of cultivation being practised, to hear the difficulties and complaints of the ordinary cultivator, and also to learn for himself the best points of indigenous agriculture, in which local tradition may often have much to teach him. Secondly, it is vital that he should visit farms in company with his instructors to check up on their instructional ability. This work is too often neglected in the pressure of other business. On such occasions, the officer should not in the first place give instruction himself; he should order the instructor to do so in his presence. For example, if the subject at issue is the pruning of coffee trees, he should ask the instructor to prune one or two trees while the farmer watches, and thus check both the instructor's own skill in pruning and his power of explaining it persuasively to the farmer.

It should be noted here that we are dealing with the officer only as an extension worker. In most cases the district agricultural officer combines this with other duties which will often take him to individual farms, e.g. inquiries into pests and diseases, agricultural surveys, or the compiling of crop reports.

What are the qualities required in the officer? Most of them can be summed up in the word "personality." It is not proposed to expatiate on this further, except to point out that very various types of personality may achieve equal success in extension work, from (for example) the bluff humorist to the erudite linguist. The ideal type of approach may vary considerably with different tribes; thus, for instance, with a very primitive people an authoritative tone and rough humour may get things done, while with a highly developed tribe like the Baganda a dignified bearing like that of their own chiefs and a more persuasive approach will be appreciated.

Linguistic ability is of great importance and in African territories should be considered in the recruitment of both European and African staff. Continuity of service in one language area helps to make it worth the officer's while to study the language, though owing to other staff difficulties it may not always be possible to arrange the ideal continuity. A point that arises with some African languages, such as Luganda, is that there is a distinct difference between the peasant accent and that of the educated classes, and it is a moot point as to whether an officer should aim at speaking like the farmers or like their chiefs in order to gain their respect.

The qualities required of the instructor are much the same. Personality is mainly a congenital character, but there should be many suitable individuals in an African population. In so far as it can be taught at all, it is by example and not by precept. The main point that concerns us, therefore, is to consider what training should be given in extension methods. It is suggested that the following are basic principles which should be emphasized:

(*a*) Instructors must be taught not to grow weary in the continual repetition of the same advice, fruitless though it may seem to them. Repetition is the fundamental principle of advertising, and there is abundant evidence of its effectiveness in the long run, especially where the same points are repeated by different individuals and through various agencies of publicity. Over a short period, however, its effect is often not apparent to the instructor concerned, and this needs to be explained to him.

(*b*) An instructor cannot usually visit all cultivators, and he should be taught that it pays best to concentrate on those whom he finds receptive. Repeated visits to a farmer who will accept no new ideas from him are a waste of time. The greatest economy of effort is obtained by bringing a few farmers who are progressive up to a high standard of cultivation which will then, it is hoped, act as an example to their neighbours, who are often more ready to receive new ideas in such a way than from an instructor. The psychology of arousing the competitive instinct by pointing out to B that A is on a good thing should also be mentioned.

(*c*) In this connexion, a tip from a psychology textbook that suggestion is often a more effective form of teaching than dogmatic statement is also worth emphasizing.

(*d*) Young instructors may need to be reminded that human nature is more easily guided by praise than blame. Even on a farm where nearly everything is wrong but a few things right, it is worth referring to the latter first. A man forced into a defensive attitude is rarely willing to take advice.

(*e*) Cultivators should be encouraged to adopt an experimental outlook and especially to try out new methods against their existing ones when they are doubtful of them. Of course in cases where an increase in yield is claimed from a new method or variety, it is unwise to teach cultivators to rely on an unreplicated experiment on variable soil as the results might appear to be contrary. But there are many cases where this does not apply. For example, in Uganda, in advising cultivators to grow sweet potatoes on ridges across the slope instead of in isolated hills (a measure which is useful in soil conservation), the objection is commonly met with that rats will burrow all along the ridges and do excessive damage to the potatoes. No cultivator I have met has ever seen this happen himself, but the *canard* appears to have spread by word of mouth through large districts, and it can only be dispelled by getting the cultivator to try a few ridges as an experiment and see that his fears are groundless.

(*f*) An instructor should not be afraid to compromise where he cannot get his full advice accepted. For example, it is desirable that all house compounds should be grassed to reduce erosion; the Baganda have a strong tradition in favour of clean earth compounds and are reluctant to do this. Rather than leave the whole compound bare, it is much better to persuade the owner to grass the greater part of it but to leave a few square yards clear in front of the door where the housewife can have the pleasure of doing her daily sweep. Again, if full mulching of coffee is unacceptable, alternate-row mulching may be agreed to; and as a matter of fact, experiments show that this is probably just as effective.

(*g*) Instructors should work to a calendar, which is best drawn up by the officer in charge of them, concentrating extension work on certain subjects which are in season for each month of the year. They thus escape the monotony and boredom of being expected to harp on the same themes all the year round, or alternatively the danger of forgetting some of the themes altogether.

(*h*) An instructor must be prepared to work with his own hands. It is only by taking his coat off that he will win the farmer's confidence, and it is very often over the refreshments which may follow a piece of shared work that his most valuable propaganda is done.

(*i*) As a corollary to this point, the instructor should always see the farmer himself practise in his presence a new method which has been explained, in order to make sure that it has been understood. Thus, to illustrate these two points together from our earlier example of coffee pruning: the correct procedure is for the instructor first to explain the new method, then to demonstrate it himself on two or three trees, then to watch the farmer carrying it out on a few more trees, to leave him to do the rest alone, and finally to return some time later and check up that it has been correctly done.

It is not suggested that the above list of points is exhaustive: any experienced officer could extend it. But it serves to show the sort of extension technique which could be taught in courses for instructors and is at present sadly lacking.

Instructors will need refresher courses at intervals, partly to keep them up-to-date in their knowledge (a result which is largely achieved among the European officers by the circulation of scientific journals and reports from experimental stations), and partly to maintain interest and to let them meet their colleagues and find out that others face the same difficulties and apparent lack of success as themselves. Such refresher courses can often be organized by the officer at district headquarters without undue trouble. Failing refresher courses, periodical conferences of the staff are quite valuable to allow them to discuss their difficulties and try to suggest improvements.

Another question in personal contacts is the approach to women. In Africa certain crops or agricultural operations are under the control of women, and it is vital that they as well as the men should understand new methods in order to effect agricultural improvement. Male instructors cannot be expected to reach the women very effectively. In Uganda, agricultural instructresses have been tried out in a small way, and while no decisive conclusion on their value has been reached, their employment has at least been proved to be practicable and they have shown that they can achieve something. It must not be forgotten that with women personal contacts are even more important than with men, for in most of Africa they are not likely to be reached by any form of publicity which involves reading.

A fruitful method of personal instruction which is often missed is that of showing conducted parties of farmers round experiment stations and farms. Such parties should be accompanied by their own local instructor as well as the one from the station who takes them round. The objection is often raised that uneducated visitors may be led astray by seeing methods in use which are not yet proved or which, while of experimental interest, are not applicable to their own holdings. My own opinion is that this objection does not outweigh the advantages to be gained by visits. It must be remembered that an experiment station usually involves large financial expenditure and every possible use must be made of it to justify such expenditure in poor colonial territories. An additional argument for such visits is that among the more educated tribes many natives are now beginning to ask questions about how the money derived from their taxes is used; they find it hard to visualize how a Government department, such as that of Agriculture, can use so much money; a visit to its larger stations, with perhaps a short lecture on their contributions to the country's progress in the past, could do much to justify the department in the public's eyes and to win popular support for it. Botanical gardens can also often be used as convenient centres for lectures, demonstrations, discussions, or organized tours. On a smaller scale parties may be taken to see local examples of model farms, such as in some territories are attached to prisons or hospitals, or even the farms of their most progressive neighbours.

Before leaving this section, it is as well to admit frankly that extension work in Africa meets with difficulties which are peculiar to the continent. Time and again an initial burst of enthusiasm by chiefs and instructors over a new agricultural method dies away as the idea loses its newness and becomes dull routine. Neither an extension worker nor an extension method should be judged by an initial success which they may achieve, but rather by the amount they can still stimulate the people in the second or third year of the newly introduced point, which is when the real test comes.

Again, personal contacts are not made easier by what one may call the irregularity of African peasant life. It is probable that a farm changes hands, or a man moves his home, far more often in Africa than in Europe. This is due to a variety of reasons: because the peasant is not tied down by permanent buildings of any value, because his house is easily burned either on purpose or by accident; because he wants to follow a favourite chief, because he has made enemies locally or is afraid of witches, because of sheer nomadic instinct, and because the sickness and death rates are much higher in Africa than in Europe. Similarly it is far more difficult to make a long-term plan, and see that it is kept to, for an African farm than an English one. An African peasant using family labour expands or contracts his acreage nearly every year because of sickness, because his wife dies or he marries a second one, because his children grow up and leave home, because he has lost money in gambling or gained it by selling his crops at a high price. All this makes it impossible to plan neat schemes of rotation for a definite acreage, and the extension worker must learn that he is largely wasting his time in trying to do so. Even where a farmer employs hired labour, both the numbers and the personnel change frequently, unlike the English labourer who may spend a lifetime on one farm; one may persuade an African to make a great improvement in looking after his cattle, and go back only to find out that he changes his herdsman nearly every year and cannot be bothered to explain the improved method to each new one.

PUBLICITY METHODS

The Local Press.—This is taken first because it is at present often the organ by which the largest numbers of people can be reached. It is difficult to estimate the circulation value of African newspapers because in countries where papers are scarce each copy may be passed on to several readers, or read aloud, and the number of people reached may be considerably larger than the total of copies sold. African newspapers are also generally small in size, and in the shortage of vernacular reading matter there is probably a greater tendency than in Europe for them to be read from cover to cover, including articles of no sensational appeal. At the present time in Uganda there is little doubt that at least 10,000 people a week can be reached through Luganda newspapers and magazines—a far larger number than can possibly be contacted by district touring, and probably more than can at present be reached by films or broadcasts. Considerable experience has been obtained in the regular use of the vernacular Press for agricultural articles in Uganda since 1940, and a few of the more generally interesting points may be mentioned here.

Articles should be kept distinctly short, to ensure both prompt publication by editors and perusal to the end by readers. Where a subject requires lengthy treatment, it should be chopped up into two or three short articles rather than published as one long one; if a long article is essential, the paragraphs should have sub-heads designed to arrest the attention. It has been found in Uganda that editors are willing to take the same article in different newspapers where the issues are published at about the same time (most vernacular papers in Uganda are weekly or with two or three issues a month); this form of "syndication" means that many more publications can be made with less time devoted to writing. When these articles were first published, it was not stated that they emanated from a Government department as it was thought that this might deter readers' interest. Later some editors took to printing "Issued by the Agricultural Department," and when questioned about this, one stated that his readers had thought the articles were written by him, and had not thought he could write with much authority on farming, as he was a townsman! So it appears that there is no objection to the official imprint, and the articles are now normally printed bearing this.

Many of the articles have been submitted to the research staff of the department for their comments before printing (as well as always to the Provincial Administration, and sometimes to others who may be concerned); occasionally criticisms have been received from the research staff that certain statements have not been absolutely verified by experiment, or do not apply to every district or to all possible conditions on farms in the Protectorate. This is a salutary criticism which we have always tried to meet as far as possible, but at the same time it must be realized that in short articles for the lay public it is impossible always to introduce the number of qualifications to every statement which absolute scientific exactitude might demand; it is more important to get the main points of the material for publicity clearly and emphatically set out than to quibble over trifling qualifications, and this must be accepted by the scientist from the publicity man provided always that the points are only trifling.

Articles containing personal names are always more popular than textbook sermons. This has also been found a good means of encouraging progressive farmers, who enjoy seeing their names in print as having adopted some improvement which is worthy of emulation by their neighbours. Helpful chiefs can also be mentioned; competition stimulated between one village or county and another, and so on.

A further method which might well be developed is the use of advertisements, such as has been practised in Britain in war-time by the Ministries of Food and Health and others. Such advertisements have shown that they have great usefulness and that no loss of Government dignity need be involved.

Pamphlets.—Much the same remarks apply to pamphlets as to Press articles. The didactic should be avoided, and the personal introduced wherever possible. A little story about Farmer A and Farmer B is usually effective and need not necessarily be true (the conscience of the writer can be salved by saying that it is only given as a typical example). Pamphlets have been fairly freely used in Uganda, on occasion editions running into thousands having been distributed in Buganda to all chiefs down to the rank of *muluka* chief, apparently with fair success. It might be possible to imitate the practice of the British Ministry of Agriculture in recent years, of having agricultural pamphlets and books on sale at special stalls at markets and other centres where farmers congregate.

Posters.—Agricultural posters used in Uganda in the past appear to have achieved little result. Posters issued for propaganda purposes during the war have, on the other hand, been of striking design and effectiveness. It would appear that there may be a useful future for posters professionally designed and competently printed with colour where necessary.

Broadcasting.—Such broadcasting through loud speakers as has so far been done in Uganda has been confined to urban centres. The public reached has been mainly detribalized or urban employees and includes few cultivators who farm on their own. Until this is rectified, the system is of little use for agricultural publicity, although it has been used on occasion. The first extensions are likely to be also to the larger centres of population, but for agricultural purposes it is imperative to get it out to the countryside by installations at village halls or the like. Up to the present, I have only met one man who said he had adopted a new agricultural practice because he had heard it broadcast.

Films.—The response to such documentaries as have been shown in Uganda shows that it is important that the sound accompaniment should be in the vernacular, and that as many of the films as possible should be locally "shot," showing workers wearing the clothes and using the implements of the tribe concerned. Commentary in Swahili and actors obviously of foreign tribes make the whole thing appear alien and of little concern to the peasant farmer, especially probably to the women who have seen less of the world. On the other hand films that are professionally made are infinitely better than ones locally taken by amateurs; I have seen, for example, a Hollywood film of the Tennessee Valley Authority bearing on soil conservation, which in spite of its remoteness I would prefer as propaganda to poor local films, because of its excellent presentation and photography. There is obviously great scope for a professional team making films locally.

Agricultural Teaching in Schools.—This is a specialized subject which does not fall within the scope of this article, which refers to extension work carried to the adult farmer on his own land. There is, however, one matter which is relevant, and that is the preparation of agricultural textbooks for schools, because this is likely to be allotted to the publicity section or officer of the Agricultural Department, where one exists. Preparing such a textbook involves, however, close collaboration with the Education Department to ensure that full advantage is taken of the most up-to-date practice used in school books in Britain and elsewhere; this affects such points as the length of sections suitable for classwork, provision of illustrations, inclusion of questions at the end of chapters for use in class, headings for revision, suggestions for practical work, and so on. It is also highly desirable that such books should be prepared by someone with special training or experience in dealing with publishers; much extra trouble can be caused by writing books too long or too short without first ascertaining the publishers' requirements, preparing illustrations the wrong size for the type of page to be used, forgetting copyrights or courtesy acknowledgments for illustrations, selecting an unsuitable publisher, and so on. There is sometimes great pressure to include profuse illustrations, which if numerous may involve quite as much labour and correspondence as the text, as well as much increasing the cost. At the present time there is a great and crying need for more and better agricultural schoolbooks in most colonial territories.

Agricultural Shows.—Experience in Uganda indicates that, while isolated shows may have some use, a regular series held in the same district would be very much better. The objects of the first show held in an area are often not understood; peasants have been heard to speak of them as "the games" or "the sports," and exhibitors instead of bringing in good items from their farms sometimes tend to bring in freaks such as a chicken with two heads or a cassava root in the shape of the human body! Regular annual shows would dispel such ideas, encourage a spirit of emulation, and might also do much to improve local types of crops and live stock as they have in the past in Britain.

Prizes for Good Farming.—Prizes have at times been offered in Uganda for the best farmers in an area, or the chieftainship which shows most agricultural progress, and the idea appears to be quite useful. Good publicity is obtained if the prizegiving is done by some notable either before a local native council, or at an agricultural show or some other large gathering. The actual prizes to be given present a problem. In one case a cup was given for annual competition between cultivators' groups, but it was found that after the prizegiving the local chief removed it to his own strongroom for safe custody, so that the winning group got little benefit of it! Challenge shields are also being used in Uganda. A framed certificate including a photograph of the holder is always popular, and so of course is cash.

Demonstration Plots.—These are a useful way of carrying demonstrations of new varieties, methods of manuring, etc., to villages or to the sites of markets or agricultural shows where farmers foregather. With primitive people, it is important that the actual work should be done by local people, so that they can see that there is no "magic" put on by the white man to make one plot better than the other. Some tribes however are so primitive that they cannot distinguish between the "good" and "bad" plots, and may carry away the idea that it is the latter they are meant to copy, since those in authority have put it there and sent them along to see it. On the other hand, a "bad" treatment which is made to appear so ridiculous as to be positively humorous, sinks well into the memory.

GENERAL PRINCIPLES

A number of valid general principles seem to emerge out of local experience in extension work. These are as follows:

(*a*) No method should be publicized until it has been absolutely verified by experiment under local conditions. This is a truism, but regular examples of its neglect still occur. Very rarely exceptions may arise, as when soil erosion is so advanced that urgent work becomes necessary, although the methods used might take years to prove in every detail.

(*b*) It appears to be generally better to bring training to the farmers rather than to bring the farmers to the training centre. Disappointing results were obtained in Uganda from "smallholders' courses" of two years duration at training centres; most of these men when taking up farming afterwards either failed to make good or exhibited no improvement in their methods. One reason for this is that established farmers are often unwilling to leave their homes for long periods; men who are attracted tend to be either very young or uprooted individuals, who often drift into other jobs afterwards and do not become steady farmers. As against this, there is much to be said for selecting certain villages as demonstration centres and training either all the farmers or "groups" of selected ones on their own farms; the former method has been used in Uganda at Ajeluk, Nsangi and elsewhere; the latter has had considerable success in Masaka district. Sometimes practical difficulties are shown up by work in such areas which do not appear at training centres; for example, stop-wash lines of elephant grass appeared easy to plant on the clean land of experiment stations, but difficulties were found and met on the weed-infested land of ordinary peasant farmers at Nsangi.

There are, however, exceptions to this principle, especially where very short courses of instruction are concerned. Courses lasting a fortnight at Bukalasa and Serere training centres have attracted genuine farmers and have had beneficial results, though the latter depend very largely on "follow-up" visits paid to the trainee on his farm some time after he has returned from the course.

(*c*) A very important point is to group trained cultivators within small areas for mutual support and encouragement. New-fangled methods adopted by a single isolated cultivator may be laughed out of court by his more conservative neighbours. Spatial grouping may be achieved either by training within a selected area, as outlined above, or by selecting from a single small area candidates for courses away from home, which is now generally done for such courses in Uganda.

(*d*) A principle which is perhaps not yet agreed by all, but which seems to me cardinal, is that it is easier to enforce one or two selected measures of improvement over a wide area than 20 measures in a small one. Thus in the demonstration areas of Ajeluk and Nsangi referred to, the object was to improve the all-round level of farming, and perhaps 20 or 30 different improvements were being urged on the farmers at intervals; this was possibly too much for their brain power; at any rate results were not commensurate with the effort made. On the other hand two excellent examples of single improvements are the planting of cotton rows across the slope and the closer spacing of cotton to an ideal of 3 ft. by 1 ft., each of which was concentrated on for two or three years by the entire agricultural staff and chiefs in Buganda between about 1936 and 1941, and have now become almost universal practice throughout the province. I myself feel very strongly that one or two main improvements should be concentrated on for agreed periods of two or three years in each district, to the virtual exclusion of others, which would only be taught to specially receptive farmers, and that this will prove the quickest way of getting things done in the end. In support of this, I would quote the opinions of two other extension workers. Mr. F. B. Wilson, in an article on "Emergency Food Production in Zanzibar" (*East African Agricultural Journal*, October, 1944), wrote: "Experience has proved that by far the most effective results have come from concentrating upon a single project at any one time." A writer in the American magazine *Soil Conservation* (November, 1943), speaking of the proper use of posters, says: "By selecting only one or two of the more important practices for dramatized presentation by visual methods, much war-time conservation can be effected."

(*e*) Among primitive tribes, and where the authority of the elders is still strong, a new method is often best presented, if possible, as a return to traditional methods, e.g. the grass ley can be described as a return to the ancestral method of shifting cultivation. On the other hand, with enlightened and educated tribes, an improvement often appeals more if represented as scientific and up-to-date and as being used in Europe or America. Thus to prevent erosion in plantain gardens, it is difficult to persuade the Baganda to return diligently to the traditional but neglected practice of mulching, but some who refuse this are willing to try new methods such as bunds and wash-stops. The tendency to need the latter line of psychological approach will increase as tribes become more educated, and also because the younger and more progressive farmers tend to be those who are most impatient at the control of the elders of the tribe.

(*f*) The question will sooner or later crop up of whether particular agricultural improvements are to be enforced by law. This is a matter on which opinions differ much. Generally speaking, I for one am opposed to such enforcement, and would quote the two instances from cotton cultivation given under (*d*) above as good examples of improvements carried through by persuasion alone. On the other hand, there are cases where fertility is being rapidly destroyed by extreme erosion, or where the quality of a crop is falling so seriously as to upset the country's economy, where urgent action is essential and few would deny that legal sanctions are justified. In all cases where possible, legal action should probably be postponed until the majority of farmers are already taking the required steps, and should only be used to coerce the minority of backward ones; in this case public opinion will be with the law rather than against it. This principle has been accepted as desirable in

Britain even to taking a vote among particular sections of the farming industry, e.g. in the case of certain marketing boards such as that for hops, where the majority having voted to put the industry under control, this was enforced upon the minority. There will be times, however, when events will not wait upon such a procedure.

(*g*) There appears to be a definite sequence of desirable stages in putting an improvement into force. Firstly, the improvement to be put into practice should be absolutely verified by experiment. Secondly, it should be advocated by all methods of publicity and personal contact. Thirdly, after it has been put into practice by progressive farmers or in demonstration areas or elsewhere, time should be allowed to elapse for cultivators to see the method with their own eyes and convince themselves that it is practical. Fourthly, it can be enforced legally if required. This programme cannot be hurried; a year is likely to be the very minimum period required for each of the first three stages. The success of the fourth stage can be endangered by insufficient time being given to any of the first three. This idea has been expressed by the American writers Gustavson, Guise, Hamilton and Ries in their recent book, *Conservation in the United States,* where it is laid down that "the utmost should be done to educate the farmer and the general public in the control of soil erosion and the conservation of water. If, after a reasonable period of education, the desired control is not attained, it may be necessary for a government agency to take steps towards this end" (quoted from review in *Soil Conservation*). Without the "reasonable period of education," agricultural legislation may not only fail of its end but have serious repercussions. A clear conception of the necessary stages involved will do much to forward the orderly progress of extension work.

CORRESPONDENCE

CONSERVATION OF WATER FOR STORAGE PURPOSES

The Editor, East African Agricultural Journal.

Sir,

The drying effect of trees, particularly of quick-growing trees such as gums and wattle is well known in East Africa. It has been known, too, for many years that there is a considerable difference in the amounts of water used by different types of plant to produce 100 gm. of dry matter. Mr. Glover in the January, 1946, number of this journal gave figures showing the inferiority of maize to sorghum—a fact of which insufficient advantage has been taken for years in the semi-arid areas of East Africa in which maize-growing, started as an economic move, has become a barren fetish. According to Strasburger the beech requires 75 litres and the pine only 7 litres for every 100 gm. of leaf substance. The advisability of planting plantations of gums, with high water requirements, especially on catchment areas—in semi-arid areas such as Machakos—has often been questioned.

When Mr. Grundy hints at the possibility not merely of exchanging crops which are prodigal of water for those which are more economical but of making wholesale alterations in the type of vegetative cover I consider he is on dangerous ground. What might or might not be academically possible in a country devoid of human or animal life might be a dangerous one in practice. We are not merely concerned in increasing our water supplies, vitally important as they are, but in maintaining an environment which can support life.

Thorn-bush uses water, but are we certain that the removal of all bush will not continually lower the stock-carrying capacity of the semi-arid areas? When the wind is let in by bush clearing in semi-arid areas such as the Makueni fly area south of Machakos—one of the native settlement straws to which we cling—the grassland appears to scorch up rapidly in the hot sun and dry wind to which the land is exposed. The rate of transpiration in wind has been measured experimentally elsewhere to be two to five times that in still air. While the experiments were carried out on pot plants it is probable that transpiration of grass is increased by wind in a somewhat similar manner. Evaporation from the ground and leaf surfaces will be increased similarly. The net result is likely to be deterioration and death of much of the herbage, particularly the more palatable types.

The amount of water percolating to the water table may be increased but more likely will not be. The assumption that a sufficient grass cover will be maintained on the ground to prevent run-off is a bold one in European areas where overgrazing, alas, is becoming more common; in the native areas, judging by the past forty years, it is a flight of phantasy. There are not only grazing animals but fires! The experiment of replacing forest by grassland in New Zealand is said to have been disastrous. As fertility declined, poor grasses replaced the good grasses which were substituted for the forest, and severe gully erosion later occurred.

The chief problems of water supplies in East Africa are in the semi-arid areas. Mr. Grundy speaks of "increased surface run-off and possibly erosion of soil, due to lowering of infiltration rate" caused by too much trampling of stock. Our experience in all areas but those with very absorbent soils is that erosion is certain. Parts of Ukamba and elsewhere where there is little vegetation to dry up the soil may have increased supplies of water soaking down to the water table. The multitudinous gullies and the broad sand-filled river valleys together with the hard, exposed subsoil, suggest that a very large proportion of the rainfall is lost through surface run-off.

At present, I must admit, I regard the discussion of the replacement of forest by grass as a proposal of more than doubtful wisdom. With regard to the suggestion of removing bush cover on absorptive land such as the coastal area of Kenya with a fairly high rainfall and poor water supplies, this might be worth trying experimentally on a sufficient catchment area.

In the semi-arid areas, however, the bush may have a useful part to play in affording shade, protection from the wind, and a means of regenerating the soil. In my review of the Report of Soil Conservation Committee of the Sudan also published in the January number of this Journal, I pointed out that a grass-*Acacia* cycle is regarded as the natural and desirable method of regenerating the soil in semi-arid parts of the Sudan. Similarly in the long-term shifting cultivation which was customary in Kenya years ago, and still is customary in some districts, the felling and lopping and burning of thorn-bush is the regular prelude to two or three years cropping. Cattle and goats exist on the pods and leaves of thorn trees for several months of the year in many districts. The drain upon the water supplies caused by the growth of this bush may be the inevitable price which has to be paid if agriculture and animal husbandry is to be practised at all in these unfriendly regions.

Yours, etc.,
COLIN MAHER,
Senior Soil Conservation Officer,
Department of Agriculture,
Kenya Colony.

A COMPOST FACTORY

The Editor, East African Agricultural Journal.

Sir,

After reading Sir Albert Howard's "An Agricultural Testament", I wrote to him to say how much I had enjoyed doing so and, as I thought he might be interested, I gave him details of a compost factory layout I have put in on my farm with very satisfactory results.

He was so interested in the idea that he wrote to me and said he was incorporating it in an article he hoped to have published in Great Britain, U.S.A., Latin America (in Spanish), New Zealand, and South Africa.

I am encouraged, therefore, to think that perhaps some of your readers may also be interested, and in setting out the details as follows, I hope that they may prove useful to others.

My first attempt at making compost convinced me that, so far as I was concerned at least, something drastic would have to be done about the amount of labour involved when following the usual practice.

After considerable thought I hit on the idea of enlisting the force of gravity, and to that end I chose the site for the factory on a piece of sloping ground, and levelled off 300 ft. by 20 ft., where I made the cattle standings. I then dug out the next level to a depth of 4 ft. 6 in., and on that level put 21 pits each 27 ft. by 15 ft. by 30 in. deep. Between the end of the pits and the sloping 4 ft. 6 in. wall, on the level of the top of which are the cattle standings, I put a light railway, equipped with tip trucks. The whole side of the byre on the edge of the wall has hinged gates of poles, each about 8 ft. by 4 ft. 6 in., which hang from their strap hinges and open up and out when their particular section of the byre is being cleaned. The 4 ft. 6 in. wall has a slight lip to it, which just overhangs the edge of the trucks. When the byre is being cleaned the manure and roughage is raked with fork hoes to the edge of the wall and falls into the truck. When the truck is full it is pushed opposite the end of the pit which is being filled, and tipped into it. At the far end of the pits there is a cutting, wide enough to admit a cart, and deep enough to allow the bottom of the pits to be just above the top edge of my carts which, when the compost is ready to be distributed, are brought under each pit in turn. The above arrangements enable the material to be handled without having to lift it, and consequently saves a lot of back-breaking labour.

I have had up to 200 head of cattle stabled in the byre every night, and my main problem is to collect sufficient roughage.

Apart from the labour required for cutting and carting the roughage, two boys do the whole thing. They can load two cubic yards on the carts in four minutes dead—and like it!

I have water laid on, and the watering of the material in the pits is done by hose.

When constructing my pits, the walls of which I lined with burnt brick, half a brick thick, and laid dry, I paved them with stone. Sir Albert Howard advises me that this was a mistake, and that better and quicker results would be achieved in the actual compost making by having the floors of the pits merely of earth, which should be forked over occassionally to improve the aeration. I am making this alteration as the pits are emptied. He also suggested that the number of turns—I had been making three—might be reduced to two, and I am trying that out also.

I am at present constructing a compost factory on Lord Chesham's farm, and in this case I am altering my original plan as follows:—

On the level upon which the compost pits are situated in the case of my farm, I am here going to build burnt brick walls, 3 ft. high, around each area where the pits would have been, leaving each end open. The space between these walls will be filled in the same manner as the pits would have been, and when filled will have movable frames at each end.

If the necessity of digging a pit can be dispensed with, the cutting to accommodate the carts can be correspondingly shallower, which will result in the saving of considerable labour in construction, especially in view of the ever present risk of striking a reef, or very large rock, which, if encountered, would increase cost of construction immensely. In this connexion I am going to reduce the height of the wall immediately below the cattle standings by 1 ft., making it 3 ft. 6 in., and this will still further reduce the depth necessary in the cart cutting. In place of the light railway, I am trying to obtain rubber-tyred wheels with axles upon which to fit a box the sides of which will take off. This will have the advantage of being capable of carrying the muck to any spot in the enclosure that will be the compost heap. If I fail to obtain the wheels and axles, I shall use ordinary wheel-barrows.

The brick walls and frames are, I think, essential where the atmosphere is as dry as it is here—heaps tend to dry out very quickly unless protected.

J. E. MACARTNEY-SNAPE

P.O. Iringa,
17th July, 1945.

Men commonly act on beliefs, not demonstrated truths. But the results of such action are beneficial in the field of natural resource development only if they are in conformity with truth, whether by accident or design.

Dr. Isaiah Bowman.

This subject [pure mathematics] has no practical use; that is to say, it cannot be used for promoting directly the destruction of human life or for accentuating the present inequalities in the distribution of wealth.

G. H. Hardy, quoted by
Bernal in "The Social Function of Science".

THE USE OF TRANSPORT AND POISON BAIT IN A LOCUST CAMPAIGN

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It is not uncommon for the officers who may be called upon at short notice to conduct a campaign against locust hoppers to have to set up their organization without previous experience, with very scrappy literature on the subject to which to refer, and to have no technical adviser with field experience within reach. Such, at least, was the experience of the officers detailed to conduct a campaign in the Mkomazi Gap between the Western Usambara and the South Pare Mountains of Tanganyika in May, 1944, where the hoppers were already hatched before it was possible to organize the assembly of equipment. The following notes, compiled as a result of this campaign, may be of wider interest to anyone who has to organize from scratch a campaign against locust hoppers although campaigns in East Africa have been many in the last few years and each one has produced its own problems whether of labour, transport or the supply of water, bait or zinc banding.

Although the Mkomazi campaign was undertaken at the height of the rainy season, which in many areas would have precluded the use of poison bait, the Mkomazi Gap is so dry that, while a deluge might be pouring in the adjacent mountains or on the coast, a gentle drizzle or mist at Mkomazi would keep the bait fresh throughout the day. In fact days were experienced which were so hot and dry that baiting was only possible in the early mornings and late evenings.

The open *Commiphora* bush around Mkomazi merges in the north-west into the lush grass of the Kihurio-Gonja swamps and in the north-east into the dense and almost impenetrable *Sansevieria-acacia* bush running out from the foot of the Usambaras where a stimulus is added to life by tsetse and rhino. The area involved by the infestation was some 300 square miles. Except by the Kihurio-Gonja swamps and at the foot of the Usambaras, where the population could be brought down the 5,000 feet from the mountains, the population was very sparse and had to be transported by lorry to the scene of action. The district, too, was in the throes of a food shortage so that, while turn-outs were communal and therefore not paid, it was necessary to issue posho and for this reason, as well as to ensure regularity of turn-out, muster rolls were maintained. As they could not be supplied by government, every able-bodied man was required to bring his hoe and machette (*panga*). Anyone who failed to do so forfeited his day's rations, a very necessary sanction as all work might have been held up for lack of tools. Large numbers of women also turned out in certain areas for the sake of the posho issue.

Reliable transport is of the utmost importance under all circumstances in which it is required, i.e. in sparsely populated areas for getting the labour and poison bait onto the job or where a dense population is being drawn on to deal with a neighbouring uninhabited area. Where hoppers hatch in a heavily populated area, which unfortunately seldom seems to happen, local man power is generally sufficient to cope with the invasion by beating without drawing on transport and with a minimum of European supervision. In the Mkomazi campaign, however, only ancient and decrepit lorries could be requisitioned from local Indian and Arab traders and seldom were more than three out of the six lorries in action at one time.

While the destruction of locusts has been given importance second only to destroying the Nazi, wherever feasible crops must also be protected if anti-famine measures are not to succeed anti-locust measures. It is often possible so to organize a campaign as to work from cultivated areas out into the bush, thus keeping the hopper bands at a safe distance. Scattered cultivations may have to be abandoned in order to protect bigger blocks of cultivation. In Northern Tanganyika the mature locusts have an unhappy knack of slipping across the Kenya border and laying their eggs just as the crops which have been planted with the short or long rains are a few inches high and well established. If the locusts lay their eggs in cultivated land, it is difficult to prevent considerable damage to crops. In a campaign in the Rombo lowlands of Eastern Kilimanjaro in December, 1944, a swarm of desert locusts laid its eggs in some 3,000 to

4,000 acres of well-established cowpeas and, while the invasion was successfully mopped up, the bulk of the crop was wiped out, more damage being done by the effects of beating than by the hoppers themselves.

Various opinions are held as to the efficacy of poison bait. In the corresponding campaign in the Kahe-Arusha-Chini area of the Moshi District using the same bait as that prepared for Mkomazi, the opinion was formed that the bait had little effect in destroying the hoppers. At Mkomazi some 3,500 bags of arsenic bait were laid down and destruction of hoppers was sufficiently effective for the conclusion to be drawn that without the use of poison bait, escapes would have been inevitable.

Flame throwers were not available in this campaign and, while they are generally said to be uneconomic owing to their high consumption of fuel, there were occasions when hopper bands were so dense as to fill and pass over trenches faster than they could be destroyed by the available man power and flame throwers of a portable type would have been invaluable to keep the trenches clear. As it was, destruction of these bands involved beating, trenching and baiting over a period of several days before they could all be accounted for.

The Senior Agricultural Officer, Northern Province was liaison officer for anti-locust measures and supplied ready-mixed arsenic bait on telegraphic request.

PLAN OF CAMPAIGN

In appreciating the situation before planning a campaign as much detailed information as possible of the areas of egg-laying and hopper hatchings is essential for the effective deployment of man power, transport and bait. A rapid reconnaissance to determine the topography, type of bush, cultivated areas, roads, river and swamp obstacles and the possibilities of grass burning should be made. It may be necessary to cut roads of access to infested areas before hatching takes place. If this is left too late, the labour force may be inextricably tied up in other operations. In the Mkomazi Gap the hoppers north of the Kihurio-Gonja swamps could only be dealt with in the first instance by beaters crossing the swamps as no road of access could be made in time. The effect of this beating, however, was to drive them eastwards into an area accessible to transport and therefore to poison bait, and the escapes were dealt with by this means at the end of the campaign when most of the other more accessible bands had been disposed of.

EQUIPMENT

While a reconnaissance of the infested areas is being made, it is also a first essential to collect equipment, establish a headquarters and organize the labour turn-out. If the equipment in the following list is assembled, it will form a sound basis for commencing a campaign and modification can be made as work proceeds to suit local conditions.

(1) *Transport.*

6 two-ton lorries (*reliable*) with drivers.
2 spare drivers for night shifts and to replace casualties.
Petrol supply.
Petrol reserve for emergency.
4 bicycles for long-range scouting.

(2) *Equipment for Hopper Destruction.*

Poison bait as required.
4 empty 44-gallon drums, open at top.
50 *debes* (4-gallon petrol tins) for—
  (*a*) baiting *à la* textbook;
  (*b*) drawing water for bait preparation;
  (*c*) drawing water for washing;
  (*d*) drawing water for drinking.

12 shovels for mixing bait.
2 measuring bowls (2 pints) for adding molasses.
1 packet 2–3 in. nails for *debe* handles, etc.
Zinc banding with metal pegs as required.
Hoes and *pangas* if not brought by labour.
One-man flame throwers with fuel (if available).

(3) *Arsenic Antidotes.*

3 *debes* vegetable oil.
12 bars soap.
1 bottle castor oil.
1 packet bicarbonate of soda.
1 bottle ferric chloride solution 30 per cent.
1 gallon linseed oil.
Dresser with supply of medicine (including quinine), to deal with cuts, swollen hands, etc.

(4) *Administrative.*

10 tons posho.
Measuring bowls for posho (assorted sizes).
Imprest for payment of wages and local purchases.
Muster rolls.

Stationery (pencils, paper, envelopes, memo. pads, file covers).
Telegraph forms.
Railway consignment note forms.
Maps (the best available of the area).

SCOUTING

Harris [1] gives the life history of the Desert locust approximately as follows:—

Egg	15 days.
Hopper	45 days.
Adult immature red to mature yellow	50 days.
Total	110 days.

The importance of obtaining immediate reports of egg-laying from native authorities, estates and from travellers through the district, as well as from the local permanent scouting organization, must be stressed. The plan of campaign, the assembly of equipment and the organization of labour should be completed before the eggs hatch out. Organized egg-digging also accustoms the labour force to the routine and discipline that will be required in the ensuing weeks. In the Mkomazi Gap campaign the equipment, through inexperience, was not concentrated until a week after the hoppers had emerged.

Locust eggs are laid in clusters or pods of 50 to 80 eggs over a considerable area and at many places by any particular swarm. Wherever egg-laying takes place close to inhabited areas, the boundaries should be marked and the population set at once to digging up and destroying the clusters. Every egg-cluster destroyed at this stage eliminates 50 to 80 hoppers from the subsequent campaign and also extends the campaigning season by 15 days as time will be found to be all too short where an infestation is severe.

The day-to-day organization of anti-locust measures depends for its efficiency on an adequate intelligence service. Two scouts should be sent out daily from every village in an inhabited area to locate hopper bands and report on their size and direction of movement. Where a large or medium band is located in dense bush it may be preferable to keep it under observation until it moves into a more accessible area before attacking it. Each baiting or beating party should have a scout working half a day ahead locating the successive bands to be dealt with. In this way no time is wasted and programmes for baiting and beating may be mapped out 12 to 24 hours in advance. Efficient reconnaissance will save endless delays. Baiting can only be carried on in the vicinity of roads owing to difficulties of transport, except where lorries can traverse open bush or grassland. For this reason all roads and bush tracks should be patrolled regularly, by bicycle if necessary, so that hoppers may be caught as they approach and cross them. This scouting should not be confused with the permanent district patrols whose duties are to observe the wider movements of locust swarms and locate egg-laying and hopper-hatching in uninhabited areas and on whose reports the preliminary stages of a campaign will be based.

BEHAVIOUR OF HOPPERS

"The hoppers are strongly gregarious on emergence and tend to congregate in large clusters which are continually in a state of movement. On the second or third day definite mass movements begin. The size of the hopper bands appear to increase rapidly owing to the quick growth of the individual hoppers, as well as by the amalgamation of bands."

"After the first moult (three to four days) the hoppers increase in voracity and will feed on such tough plants as sisal and Sansevieria. Damage done by hoppers is at first distinctly localized owing to their gregarious habits, and so at a very early stage they are a nuisance, more by virtue of their numbers than of their individual capacities. They tend to cluster on the outside of bushes and plants on which they may be feeding or resting, and only seek shade when the sun is very strong. Moulting is undergone on these stems and branches which can be clasped tightly, and not on the ground." (Extracts from Harris.) [1].

"Hoppers that are on the point of moulting will not feed on the bait. It has been found that they take it very readily after the moult. Therefore a very good time to bait a band of hoppers is when, say, 80 per cent of the hoppers have just moulted. They will then tend to stay on the baited area and a very good kill will be obtained. Hoppers in the first, second and third stages of development are more readily killed by means of bait than older hoppers. The older hoppers are more restless, and very active, and they are inclined to trek off the baited area quickly. It is, therefore, essential to locate all egg-deposits, and to kill the hoppers as soon as possible after hatching." [2]

The methods of destruction to be adopted against hoppers will depend on local circumstances but include—

(1) poison baiting;
(2) use of flame throwers and arsenical sprays;
(3) beating;
(4) use of zinc banding for beating or burying;
(5) trenches for beating, burying or burning;
(6) grass or bush fires adequately controlled.

SUPPLY AND PREPARATION OF POISON BAIT

(1) *Supply Arrangements.*—The poison bait in the campaign in the Mkomazi Gap was supplied already mixed on demand by the Senior Agricultural Officer, Moshi, being a mixture of coffee husks, arsenite of soda and molasses. A drum (44 gallons) of molasses was supplied in addition with each truck-load (200 bags) of bait to which it was added to make it more attractive to the hoppers and to prevent the bait from drying too rapidly in the sun. The bait arrived either dry or moist and the subsequent addition of water and molasses depended on this factor. The Senior Agricultural Officer, Moshi, required to be advised at the beginning of the campaign of the estimated total requirements of bait and of any changes in requirements in order to be able to ensure a steady supply as difficulty was experienced in obtaining labour for mixing, transport and trucks from the railways. Bait must be stored under cover in rainy weather to prevent the poison from being washed out.

(2) *Preparation of Dry Bait for Use in the Field.*—For ease and efficiency of mixing and preparing the bait, the dry bait should be tipped out into piles on the ground, five bags to each pile, and two labourers to each pile. To each pile of five bags of dry bait was added gradually two *debes* of water and this was worked over thoroughly with shovels. Then one full *debe* containing 8 pints of molasses made up with water was added and thoroughly mixed.

(3) *Preparation of Wet Bait for Use in the Field.*—When the bait was received wet only the full *debe* containing 8 pints of molasses mixed with water was added to each pile of five bags. The bait should not be too moist or poison will be lost. A handful of prepared bait when squeezed should exude only a few drops of water.

It was found that a central mixing depot at Mkomazi was preferable to transporting the bait, water and molasses to mix in the field. At this depot sufficient bait was prepared for each day's operations (200 to 300 bags) under the supervision of an African Agricultural Instructor with 18 labourers. When thoroughly mixed the bait was put up in half sacks for ease of handling and was loaded into lorries at the rate of 60 half-sacks per 2-ton truck and 100 half-sacks per 3-ton truck for dispatch to the baiting parties. If water trickles out of the bottom of the trucks the bait is too moist. Although bait should not be prepared for laying too long in advance it is worth preparing sufficient bait the evening before to start the baiting parties off first thing in the morning.

It will be apparent from the above description that ready access to water is important in siting a central mixing depot but care must be taken to avoid contaminating the water supply with poison and for this reason the containers used for drawing water must not come in contact with the bait. Whenever opportunity offers, and always before knocking off in the evening, all water containers should be filled to ensure an early start. Failure to take this precaution may hold up the start next morning by an hour or two when the essence of good bait-laying is to start at crack of dawn.

All empty poison sacks must be checked up at the end of each day's work and, in the case of our local campaign, they had to be returned regularly to the Senior Agricultural Officer, Moshi, in bundles of 20, 19 inside the 20th, for further supplies.

BAITING ORGANIZATION

The number of baiting parties will depend on the supply of bait and the distance from the mixing depot. Baiting within ten miles of the depot it was found that one lorry could keep a baiting party of one African Agricultural Instructor and 15 spreaders adequately supplied with bait at the rate of four 2-ton truck loads in the morning and two in the evening.

At 10 to 20 miles from the mixing depot it may be necessary to have two trucks to supply one spreading party. One European officer and one mixing party can control and supply up to six spreading parties. This assumes that six reliable lorries are available and that only minimum diversion for transporting labour to beating points is necessary. Generally it will be found that with a unit of six lorries, two are not available for the baiting, because they are either under repair or employed on the transport of labour, and equipment such as zinc banding, water or rations.

Personnel for an efficient baiting unit will therefore comprise one European officer in charge of:—

Mixing Party.—

Supervision: 1 Instructor.

Labour: 18 Mixers.

Spreading Parties.—

Supervision: 6 Instructors.

Labour: 90 Spreaders.

METHODS OF BAITING

To obtain the best results it is important to bait early and late, knocking off in the heat of the day, particularly in sunny weather. Bait should not all be dumped at one spot. When baiting across the front of a hopper band, half-bags should be dropped off the back of the lorry every ten yards. Where baiting at right angles to a road or track, ten half-sacks should be dropped off every 30 to 50 yards, depending on the number of belts of bait to be laid. In this way the lorry can return for more bait while the half-sacks are being spread. The half-sacks may either be tipped out on the ground and the bait spread from the heaps so formed or they may be carried around. Where baiting can be done at leisure *debes* are more convenient for spreading the bait. A number of the conditions met with will be described but, before deciding how to deal with any particular band of hoppers, the person in charge of the baiting party should make a rapid survey to determine the size and boundary of the band, its direction of movement, the best time for baiting and whether the bait sacks can be dropped from the lorry or must be carried by hand.

(1) *Resting hoppers.*—One of the most effective methods of baiting is to lay the poison bait under the bushes in which the hoppers are roosting last thing in the evening or in the early morning as they generally eat it readily on descending from their laager.

(2) *Small and medium bands.*—These can best be dealt with by laying a belt of bait three yards wide and just covering the soil in the shape of a horseshoe round the front of their advance, the bend round their flanks catching any change in the direction of their movement. Where hoppers are large and on the move this belt of bait should be laid a good 30 yards ahead of them or else the head of the column will have passed, or have changed its course, before the bait is laid.

(3) *Large bands.*—The three largest bands dealt with at Mkomazi were—

(*a*) one 2½ miles long advancing on a front one mile wide through dense bush. It was allowed to advance for a week, until it came into the open country, where it bunched up to 1.6 miles long by 1 mile wide. It was then baited and its further advance delayed by digging a trench 2 miles long round its front, one end resting on a swamp;

(*b*) one 1 mile wide by 300 yards in depth and of the greatest density, i.e. about 200 hoppers per square foot or not less than 800,000,000 hoppers. At first it was settled and feeding on lush grass and maize. After baiting it moved off to a river by which it was turned and again baited along a 300-yard front;

(*c*) one 4 miles long by 50 yards wide which had been turned by a river and was advancing along the bank. Its advance was held up by a trench and it was heavily baited. The greatest concentration of effort can be devoted to such bands and it is important to watch the banks of rivers and swamps to locate these large amalgamations of what were initially numerous small parties.

(4) *Young scattered hoppers.*—It is sometimes worth while to concentrate a dispersed band just as it is about to settle down for the night by surrounding the area with boys, driving the hoppers towards the centre and coaxing them to roost over a smaller area, bait being then laid under the bushes. [4]

(5) *Dense bush.*—In dense bush hoppers follow any tracks or roads they can find. Much bait can be saved by confining it to these tracks but, as the hopper columns are here generally very dense, the belts should run for 15 to 20 yards up the tracks.

(6) *Lush grass and crops.*—Where hoppers are settled on succulent grass and crops, they do not move great distances and a rather heavier rate of bait should be broadcast among them to prove attractive. It is advantageous to cut and remove a strip of lush grass ahead of their advance on which to lay the bait or even to cut the grass from underneath them if they are not inclined to move.

(7) *Dry sunny weather.*—Bait should only be laid in the mornings and evenings as it dries out very quickly. If it is necessary to lay it in the heat of the day, it should be laid in shady places and considerably more thickly than normal to delay drying out.

BAITING RATES

Bait should not be wasted but necessity for speed often precludes the possibility of adhering to the textbook advice of laying two to three bags per acre with, exceptionally, three times that amount on succulent grass. Supervision must be strict to ensure that the bait is not thrown away and, if time permits, spreading from *debes* is the most efficient method. Belts of bait should be not less than three yards wide and two half-sacks will suffice to spread 25 yards, just covering the ground. Where time is short the bait may be spread direct from half-sacks or from piles tipped out on the ground at intervals.

OBSERVATION OF RESULTS

Results of baiting appear at first to be very disappointing. Hoppers seldom start dying in under 24 hours and often take as long as 72 hours to die. Early casualties are hard to find as they are rapidly devoured by their comrades and it is only the later corpses which are found some distance from the bait. On occasion hoppers were found dying six or even eight days after baiting which was attributed to their having assimilated poison through their cannibalistic habits.

Escapes from large hopper bands should not be rebaited for at least 48 hours after the previous baiting. Bands which have been baited should be observed regularly to see the effects—sometimes an unbaited band will join a poisoned one so that results appear to be more disappointing than in fact they are. Poisoned hoppers are sluggish and on squeezing them they excrete a drop of brown or greenish liquid instead of a normal pellet and the plants on which they rest may also show the marks of diarrhoea. The bright yellow markings on the legs turn to orange and the body has a black, morbid look.

Although rain washes the poison out of bait, mist or fine drizzle helps to keep it moist. Hoppers were seen to try and eat dry bait on occasion, perhaps on the principle of trying anything once, while early morning dew appeared to freshen up the bait for an hour or two for many days after laying it down, and later hopper bands which passed over it were seen to pause and feed.

ARSENICAL POISONING

In running a poison baiting campaign one must be prepared for any emergency and all precautions must be taken against arsenical poisoning of persons handling the bait or the inhabitants and live stock of the local population. The following notes and prescriptions are culled from a Kenya pamphlet [3]. At Mkomazi no cases of poisoning of humans or live stock were recorded but swollen hands were common and responded readily to treatment.

(1) *Arsenical burning.*—All persons handling bait should be warned of its poisonous properties and the precautions to be taken. Finger nails should be cut short and the hands covered with a thin film of vegetable oil, especially between the fingers and under the finger nails. At the end of a shift all mixers and spreaders should wash their hands carefully with soap under supervision. Where people are mixing or handling the bait it may be necessary to put on a fresh gang after a week or so if their hands swell or become inflamed. If this condition occurs the hands should be washed with a solution of bicarbonate of soda, 1 teaspoonful in 3 pints of water. [3]

(2) *Stomach poisoning.*—When internal poisoning occurs either—

(*a*) the patient should immediately be made to vomit by tickling the throat or giving an emetic such as salt or mustard in warm water followed up with liberal doses of castor oil until medical help is forthcoming; or

(*b*) a tablespoonful of ferric chloride solution diluted with half a tumblerful of water is treated with bicarbonate of soda until no further gassing is produced (about a tablespoonful is required). A little soda in excess of this is then added and the red cloudy liquid is given to the patient. The dose may be repeated at short intervals until medical aid is obtained but, as the antidote forms an insoluble compound with the arsenic in the stomach, it should if possible be removed from the stomach by inducing vomiting before absorption recommences. [3]

(3) *Symptoms of Poisoning.*—Faintness, depression, nausea and sickness, with intense pain in the region of the stomach. These symptoms may be followed by purging and accompanied by severe cramp in the calves of the legs. There is often a sense of constriction with a feeling of burning in the throat, accompanied by most intense thirst. Pulse is small, frequent and irregular. [3]

(4) *Poisoning of Stock.*—The dose of the antidote for cattle is up to ¼ pint of the 30

per cent ferric chloride solution diluted with three or four times as much water, followed in a few minutes by about 1½ to 2 oz. of bicarbonate of soda in a pint or more of water. This is followed by ½ to ¾ pint of linseed oil. [3]

MECHANICAL METHODS OF HOPPER DESTRUCTION

(1) *Beating.*—The organization required to destroy locusts by beating alone has recently been described in this Journal by Collett. [5]

(2) *Trenches.*—Trenches are useful for protecting cultivations and dealing with large bands of hoppers but make very heavy calls on man power, particularly if flame-throwers are not available. With a task of ten yards a day for women and twenty yards for men a considerable mileage of trenches knee deep and a foot wide were dug at Mkomazi, either for the protection of crops or well ahead of hopper bands for their ultimate destruction. Points to note are that the sides should be undercut and the earth thrown on the side away from the hopper advance. The trench must then be manned adequately to keep pace with the hoppers filling the trenches, destroying them by beating, or else they will climb out and pass on. This work is arduous, needs constant supervision and must be maintained throughout the daylight hours or until the hopper band is destroyed. If zinc banding is available in large quantities it may be used to line the off-side of the trench. Where the hoppers are limited, they may be buried in the trench, but otherwise it will be necessary to empty dead hoppers out of the trench at intervals to allow room for newcomers. Hoppers like to move along the bottom of the trench and a deep sump dug every 50 yards or so will help to dispose of them. It is essential to guard the ends of trenches and gaps allowed for motor roads as the hoppers climb out at these points in large numbers. Unless supervised, natives tend to drive hoppers away from trenches before they reach them rather than allow them to enter the trenches in which they are to be destroyed. Driving hoppers into rivers is useless as they merely float across and climb out on the far bank with the aid of grass and branches lying in the water.

(3) *Zinc Banding.*—The method of use will depend on the quantities available which are seldom large. If plentiful it can usefully be employed with trenches as described above, but otherwise it is best issued at the rate of 50 sheets (each sheet is 5 ft. long) per gang of 40 to 60 beaters. With small bands of hoppers, beating alone is really quicker and just as effective as setting up the zinc bands. With larger bands the banding can be placed in the path of their advance, preferably in the shape of three sides of a square or a V, with a deep pit dug at intervals, and preferably at the angles, into which the hoppers fall. When these sumps are full, the hoppers are buried unless, as at Mkomazi, the beaters prefer first to fill their *debes* with hoppers for domestic consumption. When the banding has been erected, some people are detailed to dig the sumps on the outside of the fence while the rest of the gang drives the hoppers up to it. When the sumps are ready, the zinc bands are removed from before them and are run round the edges to prevent the hoppers climbing out. The pegs, zinc or wooden, which support the banding should be placed on the outside to prevent the hoppers from climbing up them.

(4) *Other Methods.*—Neither arsenic sprayers nor flame-throwers were available at Mkomazi and no opportunity arose for trying out grass burning.

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RESULTS OF SOME WHEAT EXPERIMENTS IN THE NORTHERN PROVINCE, TANGANYIKA TERRITORY

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When the Northern Province wheat scheme was started in 1942 inquiries made among the leading wheat farmers showed that there were some differences of opinion as to the best rates of seeding for the different varieties, as well as mixed opinions on the best time of planting. Naturally the latter varies from one wheat-producing area to another, but within any one area there were differences of opinion on that point. While two of the wheat scheme areas were contiguous with already proved wheat areas, the largest area of 15,000 acres lay in an area in which the annual rainfall had not been measured and on a type of soil which was not normally used for wheat production.

We were thus faced with some important unknown factors in wheat production. The annual rainfall could be guessed at from the natural vegetation and was put by experts at 20-25 in. per annum. Rainfall records kept since the inception of the scheme have shown the experts to have made a fairly accurate estimate. But what was not known was the annual distribution of the rainfall, nor its certainty. Unpleasant surprises have been encountered in both those factors. Another unknown factor, though one at which a fairly accurate guess could be made, was the behaviour of the soil when wet, while nothing was known definitely of its water retentive capacity. Judged by the extremely low humus content, shown by chemical analysis, one was led to anticipate poor water-retention, though the soil type suggested temporary water-logging would occur.

In the light of these uncertainties it was necessary to start experiments to discover the best period for seeding, the best seed rate and the reaction to each of those factors by the varieties chosen for production. It was fortunate that experiments could be made one year before the area went into large-scale production.

While the soil type on which the experiments were made is unlikely to be used in the near future for wheat production in the Northern Province, it is thought worth while to report on the experiments included in this paper as the results may find application in the black clays of the Machakos area in Kenya. It is also believed that the results are applicable to the dry areas of the Northern Province of Tanganyika although the soils in those areas are of a different type.

THE ARDAI AREA

The land broken for wheat was virgin grassland, occupied by the Masai and vast herds of game, and one of the better grazing areas in Masailand. The natural dominant cover was a variable stand of *Pennisetum mezianum* and *Pennisetum stramineum* with moderate stands of *Themeda triandra* scattered in the *Pennisetum* in parts of the area. These expected, and later proved to have better rainfall than the others.

The Soil Chemist in reporting on the soils, said:—

"The soils belong to the group of calcareous black clays, derived from alkali-rich volcanic rocks; and in general possess the following properties:—

A high clay content, often with much silt. The clay is siliceous, rendering the soils heavy and of slow drainage. A high exchangeable base capacity, almost saturated at the surface, completely saturated in the sub-soil. The bases are mainly calcium and magnesium, but with a high proportion of sodium and potassium. Alkalinity increasing with depth reaching a p.H. of 8 4 to 9.0 at the foot of the profile. The top soil is neutral or slightly alkaline.

Abundant reserves of available phosphates. The humus content is fairly low (1-2 per cent) for a soil where rapid growth is required because of a short period of rainfall.

The soils swell considerably on wetting and crack on drying, producing a marked columnar appearance in the soil profile, which facilitates drying of the subsoil during periods of prolonged drought.

The colour is black to grey at the surface."

The Ardai Plains lie mostly at 4,500 ft. but rise to 5,000 ft. in some areas. The annual rainfall, figures of which are only available for two complete years, is 15 in. in the driest area, where most of the experiments reported on here were made. In the wetter areas the rainfall rises to 24 in. per annum. On three years' experience the rainfall must be considered highly erratic. In two years the short rains have been good, followed by very poor long rains. The third year there was little or no rain in the short rains, but the following long rains were rather heavy and most persistent. The distribution in two areas is set out in Table I.

No temperature records are available but January to March are the hottest months and January and February are generally very dry. Strong winds blow across the plains during those months. With the onset of the long rains the temperature begins to fall until the coldest month, July. June, July and August are generally overcast and dry. The harvest falls within the last two months and into September. The temperature gradually rises from August to the hottest months of the year.

Certain characteristics of the soils under cultivation should be mentioned. When ploughing after harvest the land generally breaks up into large, very hard clods, but in some areas, particularly where the soil was not too moist at planting, harrow-ploughs can penetrate to 6 in. Given good falls of rain in the short rains the clods break down easily and disc-harrowing produces a very fine, almost too fine, tilth. No work can be done on any of the land for at least three days after a fall of 1 in. of rain, and rain tends to run the surface together, forming a crust on drying, which later cracks into small flakes. Any cultivation of the land too soon after rain leads to badly packed land and this happens in drilling if one is forced, by a delayed programme, to get on the land before it is quite dry enough. The tractor wheels leave compressed tracks in the soil which later dry out into hard strips. Although the soils lack humus they are remarkably retentive of moisture provided there is a good tilth. In 1945, when the long rains were a failure, several blocks of Kenya Governor sown after 3 in. of rain at the end of May produced crops of four bags per acre, although

TABLE I.—RAINFALL IN INCHES AT TWO FARMS ON THE ARDAI

		OCTOBER			NOVEMBER			DECEMBER			JANUARY		
		Rain	Days of rain	Highest fall	Rain	Days of rain	Highest fall	Rain	Days of rain	Highest fall	Rain	Days of rain	Highest fall
A	1942–3	No	record		No	record		No	record		1·19	5	0·58
	1943–4	Nil	Nil	Nil	0·93	5	0·43	0·11	3	0·06	1·09	3	0·69
	1944–5	0·30	3	0·25	No	record		2·54	5	1·40	1·62	4	0·77
B	1942–3	No	record		No	record		No	record		1·55	5	0·42
	1943–4	0·03	1	0·03	0·87	5	0·41	0·43	2	0·37	0·35	4	0·25
	1944–5	0·94	4	0·57	7·80	9	3·33	2·50	2	1·46	1·24	4	0·62

		FEBRUARY			MARCH			APRIL			MAY		
		Rain	Days of rain	Highest fall	Rain	Days of rain	Highest fall	Rain	Days of rain	Highest fall	Rain	Days of rain	Highest fall
A	1942–3	5·04	12	1·75	0·92	8	0·35	2·89	12	1·65	1·39	7	0·38
	1943–4	2·01	6	0·95	4·74	10	1·70	6·18	23	1·22	1·49	9	0·39
	1944–5	3·86	8	2·00	1·14	9	0·34	0·58	7	0·22	2·80	13	1·52
B	1942–3	8·00	9	4·75	1·29	9	0·48	5·18	13	2·01	1·36	8	0·35
	1943–4	3·90	7	1·57	5·28	10	2·05	9·64	22	2·73	4·53	9	1·10
	1944–5	3·31	7	2·15	1·01	5	0·70	0·30	6	0·21	3·88	12	1·75

		JUNE			JULY			AUGUST			SEPTEMBER			
		Rain	Days of rain	Highest fall	Rain	Days of rain	Highest fall	Rain	Days of rain	Highest fall	Rain	Days of rain	Highest fall	TOTAL
A	1942–3	0·28	4	0·19	0·25	3	0·17	0·02	1	0·02	Nil	Nil	Nil	11·98*
	1943–4	0·11	2	0·08	0·03	1	0·03	Nil	Nil	Nil	0·22	3	0·14	16·91
	1944–5	0·05	1	0·05	0·01	1	0·01	0·05	1	0·05	Nil	Nil	Nil	12·96*
B	1942–3	0·54	3	0·44	0·32	3	0·23	0·02	1	0·02	Nil	Nil	Nil	18·26*
	1943–4	0·32	2	0·31	0·08	2	0·05	Nil	Nil	Nil	0·40	3	0·31	25·83
	1944–5	0·04	1	0·04	0·11	2	0·06	0·13	3	0·05	Nil	Nil	Nil	21·56

no further useful rain fell afterwards. When the land was ploughed in October moist soil was turned up at 6 in. in several fields. Under persistent rain there is a tendency for the soils to become temporarily waterlogged.

Time of Planting Experiment

This experiment was made in two seasons, 1943 and 1944. In the first year the long rains practically failed and were very late; in the second year they were heavy and persistent. The experiment was not repeated a third year as it was considered that the results covered the extremes of rainfall on the Ardai, and results from the two years had been practically identical.

Four varieties, Kenya Governor, 192, Simpson's L3 and Simpson's Rongai were used at three times of planting—March, April and May. The trial was laid out in six randomized blocks, each of twelve plots. In the first year the plots were 1/89th acre after discard. In the second year they were 1/59th acre and the yields for 1943 have been adjusted to 1/59th acre.

In 1943 the experiment was planted on newly broken land. No drill was available and the plots were sown with a Planet Junior single-row seeder. The following year the land had carried one crop of wheat and the plots were sown by a 20-row seed drill. The Planet Junior was not ideal for the work on the clay soils as it had to be pulled by one man and guided by another, which meant much trampling of the soil and too much compaction when it was wet. This had an adverse effect on the growth of the wheat.

The rains did not start in 1943 until 25th April, but a shower at the end of March enabled the first planting to be done on 2nd April. The two later sowings were made on 30th April and 14th May. The rains stopped on 10th May and only 0.3 in. rain fell on the late-sown wheat. In 1944 the rains started spasmodically at the beginning of March and set-in in earnest at the end of that month. April was very wet but the rains ceased abruptly on 20th May and no further rain fell. The experiment was sown on 23rd March, 18th April and 19th May.

A seed rate of 65 lb. per acre was aimed at but when the Planet Junior was used the actual rate was nearer 100 lb. per acre. Using a drill in 1944 the desired seed rate was obtained.

The early-sown wheat in 1943 went through very adverse conditions for three weeks after sowing, when no rain fell. The stand was reduced by the droughting of plants and, later, aphis attacked all varieties and caused premature drying of the foliage. Stands from the later-sown wheat were better but due to the lack of rain, development was poor. In 1944 good stands were obtained from all times of planting. A feature of the development of the wheat was a physiological tipping of the ears, particularly bad in 1943 in Simpson's L3 and Simpson's Rongai. Up to a half of the ear, from the tip downwards, failed to set grain. This was particularly noticeable in the medium and late times of planting. It was less serious in 1944, but did occur in the later sowings, again more prevalent in the two Simpson's varieties.

A feature of the late plantings in both years was the very poor root growth in all varieties. There was particularly no development of the secondary, adventitious, root system, so that anchorage of the plants was almost nonexistent and a high proportion of lodging occurred before harvest. Had the wheat been cut with machinery up to 50 per cent of the crop would have been lost.

Leaf rust was general in both years, particularly in 1944 and affected both Simpson's varieties and 192 more than the Kenya Governor. Foliage dried up prematurely, leading to some premature ripening of the ears with a consequent lowering of quality of the grain. Stem rust was absent in 1943, but Kenya Governor had a very slight infection in 1944.

All plots were harvested by hand before they were dead ripe. The wheat from each plot was stooked on that plot and threshed by a Little Gem thresher and hand-winnowed. Losses of grain were negligible so that the yields represent a 100 per cent crop. The results discussed below are all statistically significant at the 1 per cent level, except where specified.*

The Results†

The earliest-sown wheat gave the highest overall yield, 4.27 bags per acre, and each later time of planting showed a progressive drop in return at 3.27 and 2.98 bags per acre, although the last yield is not quite significantly different from that for the wheat planted at the intermediate date. Kenya Governor at 4.30 bags per acre and 192 at 3.94 bags per acre yielded equally well, but both were better than the Simpson's L3 and Rongai, which yielded equally at 3.02 and 2.77 bags per acre respectively.

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* *Significance at 1 per cent level.*—This term means that similar results to those in this experiment could be expected 99 times out of 100 trials. In other words the results are highly conclusive.

† In presenting the results of the experiments the usual tables setting out yields in full have, at the Editor's request, not been included.

In 1944 the drop in yield of the two Simpson's wheats was very marked and the reaction to later sowing significantly different from that of Kenya Governor. Whereas the latter gave 4.97 bags per acre for the earliest sowing and 3.73 bags per acre for the latest sowing, Simpson's L3 dropped from 5.18 to 2.74 bags per acre, and Simpson's Rongai from 4.45 to 2.62 bags per acre.

Comparing mean yields from the three times of planting in the two seasons, the earliest planting gave one bag per acre more than the intermediate and late plantings. 1944, with its heavier rainfall, was a very much better year for wheat than 1943, the overall difference for all these times of planting being ¾ bag per acre, but the earliest time of planting gave 1½ bags more in 1944 than in 1943. Perhaps the most significant result shown in this comparison was that, in both a dry and a wet year, early planting is of the greatest importance and apparently more so in a wet year than a dry one. In 1943 the mean yield for early sowing was 3.58 bags per acre, that in 1944 5.02 bags per acre. In 1943 the drop in yield from early to late sowing was 0.71 bags per acre; in 1944 it was 1.8 bags per acre.

The four varieties showed different responses to the improvement in conditions in 1944. 192, Simpson's L3 and Simpson's Rongai each gave significantly higher yields in the better year, the most marked response being obtained with Simpson's Rongai which gave mean yields for all times of planting of 2.02 and 3.52 bags per acre in the two years. Kenya Governor did not show a significant response. These results are statistically significant at the 5 per cent level.

General Conclusions

It should be stressed that these results apply only to a restricted area of wheat land in the Northern Province of Tanganyika, but it is most probable that they would be found to apply in other areas similar in soil or climate.

(*a*) Early planting is essential to obtain maximum yields. The best period of planting lies between the first good rains in March and about 7th April.

(*b*) Early planting is important in dry and wet years.

(*c*) It is more important to plant Simpson's wheats early than 192 and Kenya Governor. In fact Kenya Governor can yield quite well with very late sowing.

(*d*) In the restricted period of the trials, Kenya Governor and 192 have shown themselves better suited to the conditions on the Ardai than Simpson's L3 and Simpson's Rongai.

VARIETY X SEED-RATE TRIAL

The remarks on rainfall, agricultural operations, method of sowing and layout, prefacing the account of the previous experiment, apply to this experiment. The same four varieties were included in the trial and three seed-rates were used—50, 75 and 90 lb. per acre. The layout was the same but very small plots—1/77th acre were used in 1943. In 1944 using a seed drill, it was possible to put in larger plots of 1/56th acre. The yields for 1943 have been adjusted to the larger plot size.

In 1943 the experiment was sown on 12th May, under ideal soil conditions and after the rain had finished. Only one small shower fell on the wheat after sowing and a full germination was not obtained. The yields were surprisingly good for such late sowing. In 1944 the experiment was sown on 7th April, again under excellent conditions and good rains fell for six weeks after sowing.

Development of the wheat in 1943 was poor, though better than in the time of planting trial. Aphis attacked all varieties but did not cause a great loss of plant. Tipping of the ear was very prevalent. In 1944 the wheat grew well but some droughting and premature ripening occurred in the Simpson wheats. Leaf rust was heavy in 1944 and Kenya Governor was lightly attacked by stem rust.

The Results

The differences between mean overall yields for different seed rates, though apparently favouring the lowest, were not statistically significant. A seed rate of 50 lb. per acre gave 4.93 bags per acre, that of 90 lb. 4.77 bags per acre. In other words, in the conditions under which the experiment was made, and over two years, the yield from a seed rate of 90 lb. is no higher than from one of 50 lb. and there is no point in exceeding a seed rate of 50 lb. given good-class seed-wheat.

Analysing the figures more closely, certain trends were shown within varieties; and though these were not significant, they might have been more pronounced had it been feasible to repeat the experiment for two more seasons. In the dry year 1943 both the Simpson's varieties showed a progressive reduction in yield with an increase in seed rate, most marked in Rongai, which fell from 3.82 to 2.84 bags per acre. While the trend in L3 was not as marked, judging by the vegetative characters of the wheat, it may indicate the same thing as in Rongai. In the wetter year yields from all seed rates of these two wheats were extremely close.

The mean yields for varieties were in the same order as in the time-of-planting trial, but Kenya Governor, with a mean yield of 5.64 bags per acre, outyielded 192 in this trial, owing to heavy leaf rust in the latter. The two Simpson's varieties yielded equally well at 4.35 and 4.09 bags per acre, but both below 192.

Analysing the yields from the different seed rates for the two seasons, no differences in yield were recorded for the individual seed rates. It had been expected that in a wetter season, such as 1944, yields from higher seed rates would outstrip that from the lowest seed rate. This was not, however, the case. On the other hand there are indications, mentioned above, that in a dry year a higher seed rate may depress the yield of some varieties.

From the foregoing it therefore appears that there is no advantage to be derived from seeding more than 50 lb. per acre in either a wet or dry year. This is fortunate, since at the time the wheat is sown, the rainfall which may follow is unknown.

The reactions of Kenya Governor, Simpson L3 and Simpson's Rongai to the better conditions in 1944 were similar to those in the time-of-planting experiment, the two Simpson's wheat showing a significantly greater increase in yield in the wetter year than Kenya Governor. But as in the previous experiment, neither yielded as well as Kenya Governor or 192, even in a wet year, and the varieties cannot be considered really suitable for the area. They were originally chosen for production as they were said to be resistant to all forms of stem rust except K2 and K3, having only a slight susceptibility to those forms. This has not proved the case, for in 1944 fields of Simpson's Rongai were severely attacked by stem rust and in 1945 a large area of L3 was almost destroyed by it. Further tests in Kenya have also shown that the Simpson's wheats are susceptible to other forms of stem rust.

Variety 192 did not yield better in the 1944 trial than in that of 1943, although it had done so in the time-of-planting experiment. This was due to the very heavy attack of leaf rust in the wetter year and the good yield from early-sown 192 in 1944, which raised the overall yield considerably in the time-of-planting experiment in that year. In areas where the soils are not first class and where the long rains stop suddenly in May yields from 192 can be seriously reduced if the wheat is attacked heavily by leaf rust. This has not occurred, however, in areas of rich soils with good moisture-retention, as at Mbulumbulu and Oldeani.

General Conclusions

(*a*) In the Ardai area with its uncertain rainfall a seed rate of 50 lb per acre is sufficient for all varieties.

(*b*) If the season is a dry one, a factor which cannot be foretold at planting, a higher seed rate than 50 lb. per acre may depress the yield of both the Simpson's varieties. No increase is obtained by sowing either Kenya Governor or 192 above 50 lb. per acre in either a dry or wet year.

VARIETY AND SEED-RATE TRIAL, 1945

In view of results from the field and from the experiments discussed above, it was decided to drop Simpson's Rongai in the Ardai area in 1945. The seed-rate trial was therefore changed to include only two varieties with two lower and a higher seed rate than those in the previous trials. Although this experiment has only been made in one year it is considered worth including as the results support the previous trials.

1945 was a particularly difficult season. Although very good short rains fell from November to February, the March and April rainfall was very low indeed. No useful rain fell after the first week of March until 26th May, when over three days there were 2.53 in. of rain. The experiment was sown on 30th May with considerable doubts of reaping a crop. The experiments had been moved, however, from the area occupied in 1943 and 1944 to a higher-rainfall area of better soils. Much of the short rains had been retained by careful cultivation, and a surprisingly good crop was obtained, although no further useful rain fell after sowing.

The land was ploughed in September, 1944, turning in the stubbles. It was harrow-ploughed in December and received two disc-harrowings in February and March.

It had been intended to include the varieties 192 and SL3 in the trial, but with the late date of planting it was decided to replace the SL3 with Kenya Governor. The seed rates were 30, 45, 60, 75, 90 and 120 lb. per acre. The trial was laid out in randomized blocks each of twelve plots, each 1/45th acre. Soil conditions were good when the wheat was sown and a good germination and stand were obtained. The wheat developed surprisingly well, although it produced only a short straw. Only very slight signs of droughting were apparent after the ears were extruded and no tipping of the ears occurred. Some leaf rust developed in 192 and a very slight infection of stem rust was found in Kenya Governor. Neither variety apparently suffered from these attacks. The more thickly sown plots of Kenya Governor appeared to be slightly ahead of the thinner plots when they were cut. It was noticeable that much of the straw in the more thickly sown plots was thin and poor, with many stunted plants and poor ears. The thinly sown plots were much better in this respect and had rather more tillers. A feature of the plant development was a failure to produce adequate secondary roots, so that the anchorage of the plants was almost non-existent and much wheat lodged before harvest. The Kenya Governor gave first-grade wheat, the 192 third grade, from all treatments.

The Results

The mean yield from a seed rate of 30 lb. per acre, 5.26 bags per acre, was lower than from all other seed rates. Although the mean yield from the seed rate of 45 lb., 5.64 bags per acre, was lower than from the higher rates of 75 lb. and 120 lb., the four treatments 60-120 lb. per acre all yielded equally, yields ranging from 5.80 to 6.05 bags per acre, and the yields from 60 and 90 lb. per acre were not better than that from 45 lb. per acre. These results support, in general, those from the two previous years. Nothing is to be gained by sowing at a higher seed rate than 60 lb. per acre, while seed rates as low as 45 lb. may give yields almost as good as the higher rates.

The response of the individual varieties to the different seed rates, though apparently showing very marked differences, is not significant under the conditions of this experiment. The trend would appear to show that 192 could be expected to yield a full crop at a lower seed rate than Kenya Governor.

With the very late date of Planting Kenya Governor yielded considerably better than the 192, which was also the case in the field.

CULTIVATION TRIAL

This trial has again been made for only one year, but the results are so marked that it is considered worth recording them, particularly as they show the value of ploughing-in stubbles in dry areas.

The treatments included in the trial were:—

(*a*) Ploughing-in stubble.

(*b*) Burning stubble and ploughing.

(*c*) Harrow-ploughing stubble.

(*d*) Burning stubble and harrow-ploughing.

The following sub-treatments were superimposed on the above:—

(i) A second ploughing.

(ii) A second harrow-ploughing.

(iii) No second deep cultivation.

The land on which the experiment was made had been broken in 1943, and carried a crop of Simpson's Rongai in 1944, giving four bags per acre. The crop was harvested by combine and due to breaking of the straw the wheat had been cut low, so that there was a considerable amount of straw on the land.

The trial was laid out in five blocks, each of four main plots each subdivided into three sub-plots. The sub-plots after discard of edges at harvest were 1/80th acre.

The main treatments were made on 15th September, 1944. Owing to the rather soft conditions of the soil both deep cultivations were rather deeper than normal, the plough penetrating to 9 in. and the harrow-plough slightly less. The stubble and straw were well turned under by the plough but the harrow-plough left about 20 per cent uncovered. There were good falls of rain in November which compacted the soil well and brought on a fairly heavy growth of weeds. The only apparent difference between the plots was the absence of volunteer wheat from the burnt plots, whereas there was a fair stand in the unburnt plots. On the uncultivated headlands the weed growth was much heavier than in any of the treatments.

The sub-treatments were made on 12th December. Those plots receiving no second deep cultivation were disc-harrowed the same day, with very good results. All plots received two subsequent disc-harrowings in February and March.

Owing to the very late rain the trial could not be sown until 29th May. There had been good "short rains" and some good rain in January and February, so that when the plots were sown the straw and stubble had almost completely broken down. The variety used was Kenya Governor, sown at 65 lb. per acre. A good stand was obtained and development of the wheat was very fair considering the complete absence of rain after sowing. Two months after sowing, when the wheat was coming into ear, it was possible to pick out the unburnt plots by eye. In those plots the wheat was taller, showed better stands and generally looked less affected by the dry conditions. Later it appeared that the wheat in the burnt plots ripened rather more quickly than that in the unburnt plots. There was little or no development of a secondary root system, so that at harvest much of the wheat had fallen over. The sub-plots were harvested by hand and stooked on the plots.

The Results

The most striking and consistent result, significant at the 5 per cent level, both in the mean yields and those shown in the sub-treatments, is the considerably higher yield from all plots in which stubble was turned under. The mean yield for ploughing and harrow-ploughing stubbles was 6.48 bags per acre, that from burnt plots 5.08 bags per acre, a difference of 1.4 bags per acre in favour of turning under stubble. As mentioned before, the 1945 season was a remarkably dry one following good "short rains." The addition of humus by ploughing under the stubbles no doubt greatly assisted the retention of the early rains in the soil, leading to this marked increase in yield. The experiment is being repeated on the same plots in 1946, and it is hoped that a wet season may occur, so that results from two contrasted seasons may be compared.

There was no difference in yield from plots which had been ploughed and those which had been harrow-ploughed, each giving a mean yield of 5.78 bags per acre. Thus, at least in the first year after breaking new land, there is no disadvantage in using the harrow-plough provided it penetrates the soil adequately.

Yields from a second deep cultivation—5.72 bags per acre for harrow-ploughing and 5.82 bags per acre for ploughing—were not better than that from the control plots, which gave 5.87 bags per acre. It would therefore appear that, provided weed growth has not got out of hand, a second deep cultivation of the soil type in which the trial was made is of no intrinsic value. It should be resorted to only if harrowing cannot control the weed growth.

The quality of the wheat from plots in which the stubbles had been turned-under showed a tendency to be better than in those plots in which the stubble had been burnt.

SUMMARY

The results from variety x time-of-planting, variety x seed-rate and cultivation trials on black clay loams in a dry area are described.

The time-of-planting trial showed that in both wet and dry seasons it is essential to plant early to obtain maximum crops. This is more essential when planting Simpson's L3 and Simpson's Rongai, and to a lesser extent 192, than Kenya Governor.

The seed-rate trial showed that there is no advantage in sowing more than 60 lb. per acre of any variety and lower seed rates of 50 lb. can give as good yields as higher seed rates. There is some indication that in a dry year higher seed rates may seriously depress the yields from Simpson's wheats.

In one of the variety trials Kenya Governor and 192 yielded equally well but in two others 192 was not as good as Kenya Governor. Both out-yielded the Simpson wheats. In fact it is doubtful whether, in yield, the latter are suitable for the area. Moreover, their stem-rust susceptibility is a serious disadvantage. With extremely late planting as in 1945, Kenya Governor gave considerably better yields than 192.

The cultivation trial demonstrated the great benefit of turning-under stubbles in a year of good "short rains" but very poor "long rains." Burning the stubbles reduced the overall yield by 1.4 bags per acre. There is no intrinsic value in giving a second deep cultivation.

NOTES ON THE HIDES AND SKINS INDUSTRY

PART I

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"The virtues of living skin are so obvious to the owner that it is not surprising that one of the first activities of prehistoric man was to discover how to make use of other skins besides his own." [1]

Skin when removed from an animal quickly putrifies if left in the moist state but becomes hard and rigid if allowed to dry; so, through the ages man developed treatments which would render skin loss liable to putrefaction and at the same time adapt it to a wide variety of uses. After such treatment skin becomes "leather" and leather can be made from the skins of practically all animals, including birds, reptiles and fishes. Many skins are too thin, too small or available in insufficient quantities to make them of commercial value and to-day most leather is made from ungulate integuments. Hides from East African buffalo, zebra, etc., have a commercial leather value but the present article confines itself to the hides and skins of cattle, sheep and goats.

Although the trade distinguishes between hides and skins the difference is a conventional one, the term "hide" being reserved for the covering of a large animal and "skin" for that from a small animal. Goats and sheep always yield skins but there is no easily distinguishable line to indicate where a young bovine ceases to yield a calfskin and yields a hide. For convenience in the East African trade any bovine integument weighing 4 lb. dry weight or less is classed as a calf skin and anything over this weight as a hide.

Whether regarded as a potential source of meat or as a factor contributing to an accelerated rate of erosion, much is heard of the large live stock population of East Africa, but it is not generally appreciated that the monetary value of the hides and skins exported has, for many years, placed these raw materials of the leather industry fifth or sixth on the lists of exported goods from each of Kenya, Uganda and Tanganyika. In fact, during the nine years 1936-1944 the annual export value of these products has averaged £578,334 distributed as follows:—

EXPORTS OF HIDES AND SKINS

Country	Sun-dried Hides		Shade-dried Hides		Sheep and Goat Skins		Total Value
	Tons	£	*Tons*	£	*Tons*	£	£
Kenya	1,007	47,052	1,654	118,064	1,587,800	85,496	250,612
Uganda	704	36,271	661	49,616	358,052	21,071	102,958
Tanganyika	2,267	131,679	632	40,030	990,758	41,055	220,764
TOTAL	3,978	215,002	2,938	215,710	2,936,610	147,622	578,334

At the beginning of this nine-year period the local tanning industry took negligible quantities of hides and skins but, in spite of war-time controls, has now reached an annual consumption of about 850 tons hides and 250,000 skins, so that the average value of the hides and skins industry can be safely put at over £600,000. This, however, does not represent the real potential value of these raw materials, because, as will be seen later, much damage which could be avoided is done to hides and skins during their removal from animals and their subsequent cleaning, drying and storing prior to export. One of the objects of this article is to call attention to known faults in preparation and to indicate how these can be avoided in the light of experience gained by exporters and tanners, the veterinary departments and the Imperial Institute [2].

The price of hides and skins is determined by their value for leather production and this is considerably affected by the type of leather to be produced, the condition of the animal, the type of animal and the method of preparation and curing. For example, sheepskins will have little value for sole-leather production but may be very valuable for making gloves. Hides and skins from starved animals will be of less value than from well-nourished stock, whilst hides from humpless European cattle are priced higher than humped Zebu hides. Also, no matter how perfect hides may be when removed from animals their value can be reduced to that of low-priced glue-stock by careless preparation; whilst the most perfect method of preparation and curing cannot make a first-class article from hides badly scarred by disease or brand marks. Tanners learn by experience what out-turn of leather hides and skins of certain origins or types will yield and are, therefore, able to state what price they can pay for them in relation to ruling world prices. The export value of the hides and skins trade is thus fixed by the quality of the article exported and the object of the local industry should be to see that quality is improved to as high a level as possible.

Unfortunately between the time animals are born and the time their hides or skins are exported, the latter have been exposed to so many natural and human activities that it is not possible to affect the final quality by directing attention to one point only in their development. A further trouble in connexion with the general improvement in hides and skins is that in animals slaughtered for meat, the hides or skins may be worth not more than 10 per cent of the value of the meat and so every endeavour is made to obtain the maximum amount of meat at the expense of gouges and cuts in the hides or skins. If to this is added the fact that butchers often employ casual labour whose sole object is to get the hides or skins off the carcasses quickly and who do not care how they achieve this, it is easy to realize the enormous amount of damage which can be done. On the other hand, where animals die of disease or starvation and the only saleable parts of them are their hides or skins the animals may have been dead some time before the hides or skins are removed and the latter may have become seriously damaged by putrefaction, and may suffer further putrefactive damage during their journey in from the bush to be dried near the owner's hut.

It is, however, quite impossible to estimate the monetary loss to the hides and skins industry through the various causes affecting the quality of the hides and skins. Some of these causes operate whilst the animal is alive but the greater percentage of the financial loss is caused through faulty flaying, cleaning or drying. Most of this damage could be avoided, or at least considerably reduced, by the exercise of proper care and, if nothing else were achieved than to deliver for export well flayed, suspension-dried hides and skins of good shape and trim, free from gouges, cuts, holes and brand marks, the increased monetary return to the industry and particularly to the producers, would be considerable and more than repay the extra trouble taken.

The Preparation of Hides and Skins

By the "preparation" of hides and skins is meant all the operations to which they are subjected from the time the animals die until their hides and skins are sold, and includes flaying from carcasses, washing, fleshing, drying, folding and even storage.

The Flaying of Hides and Skins

The object should be to produce symmetrical and rectangular-shaped hides or skins with as few irregularities in outline as possible. The greater the deviation from straight outlines the greater the waste to the tanner as all such irregularities have to be cut away and possess only glue-producing value. The final shape, known as the "pattern" in the trade, is largely determined by the position of the opening cuts when removing hides or skins from carcasses. The first cut should follow a central line from the anus along the belly to the throat. This allows the pattern to be symmetrically balanced about the backbone line. The next operation is to cut round the legs at the level of the knees and hocks and then to open down from the back of the hocks to the anus and from the inside of the knees downwards and forwards to a point just in front of the sternum. It is common practice in East Africa to open down from the inside of one hock, through the udder or scrotum, to the middle of the opposite hock, but this is not to be encouraged as it gives a triangular-shaped bulge between the back legs and the tail portions of the hides, or skins, which is eventually trimmed off by the tanner as shown by the dotted line at B in Figure 3. The position of the correct opening cuts are shown at Figure 4. As taken off the carcass, many hides and skins have small irregular pieces jutting out from their general outline and these should be cut off before drying. In the same way, if the shank portions are long, these should be trimmed off just above the level of the knees or hocks. Hides and skins dried and sold with these projecting irregular pieces left on, or with long shanks, are referred to in the trade as being of bad "trim," and the exporters have to cut these unwanted pieces off before export. Trimming dried hides and skins is time-consuming as well as hard work, and naturally well-trimmed hides and skins are more attractive to exporters than untrimmed stock. Figure 1 shows the outline of a hide of good pattern and good trim whilst Figure 2 shows one of bad pattern and bad trim. The dotted lines indicate where trimming should be done but nothing can be done to alter the pattern.

Cattle.—Once the opening cuts have been made, hides should be cut away from the carcasses, using a knife with a curved blade, and never should sharp-pointed knives be used because of the serious risk of gouge marks, cuts and holes. The hides should be pulled away from the carcass with one hand whilst the other directs the knife's edge so that the plane of the blade lies as flatly as possible to the plane of the hide; the greater the angle between the planes of the hide and knife blade the greater the chance of gouging. Once the flaying has been started in this way, the less the knife is used the better. Natives, left to themselves, do not attempt to remove hides other than with a knife and usually resist efforts to induce them to remove hides with their fists, elbows, hammers or other non-cutting implements. Usually the person introducing such methods gives up before he has succeeded in inducing the natives to adopt the better method and it has become widely believed that hides cannot be removed from Zebu cattle in the same manner as in Europe. This is not true, and the Tanganyika Veterinary Department is now introducing the use of hammers in all abattoirs under its supervision, whilst the use of knives for removing the butt portion of hides is forbidden in the Nairobi abattoir, where an unsharpened piece of steel, roughly semi-circular in shape and fixed to a wooden handle, is used to push or knock off hides. Knives have to be used for removing hides from difficult portions of carcasses but their use should be kept to a minimum.

Goatskins.—After making the opening cuts and clearing enough space from these cuts to insert the hand, skins should be pushed or pulled off entirely by hand.

Sheepskins.—These should be pushed or pulled off by hand in the same way as for goatskins, with perhaps a little help from the knife when skinning the subcutaneous fatty deposits.

In some districts (e.g. Kampala) skins are pulled off sheep and goats without making any opening down the belly and are then dried flesh side out, and sold in this "cased" form. This is an excellent example of how natives can, when accustomed to the process, skin sheep and goats with their hands and there is no reason why this method should not be developed throughout the whole of East Africa with considerable benefit to the general average skin quality. As to whether skins are better dried in the cased form or flat, after opening up the belly portion, I consider they should all be dried flat even if this means opening up the belly after removal from the carcass in the cased form.

Once animals have been flayed the hides and skins should be removed for washing at once and not allowed to lie about where they will become soiled with blood, stomach contents or dirt. Also, when animals are slaughtered away from abattoirs, it is common to see the carcasses opened and cut up on the hides or skins. This should never be done.

Curing of Hides and Skins

Whilst still on living animals, hides and skins possess considerable powers of resisting attack from saprophytic bacteria but, once the animals are dead, the hides or skins quickly lose this property. The development of bacteria in the integument of dead animals causes the skin proteins to decompose and the hides and skins to putrefy. When, as often happens in the case of animals dying of disease or starvation, the hides and skins are not removed until some time after death, putrefaction is sufficiently advanced for the hides or skins to retain the odour of putrefaction after drying; and because there is often no visible indication in the dried hide of the extent of the putrefactive damage, such hides and skins can realize only the lowest prices. Hides and skins should therefore be removed from an animal as soon as possible after death.

When hides or skins are being removed from carcasses they pick up from their surroundings large numbers of saprophytic micro-organisms which, so long as the hides or skins remain moist, quickly develop and cause putrefaction. The rate at which putrefaction occurs is naturally more rapid in hot than in cool areas and it is most important over the major portion of East Africa to prevent or reduce such decomposition to a minimum by starting the curing process as soon as possible after the death of the animal. There are three general methods of preserving hides and skins, namely, air-drying, salting and pickling; but in East Africa the trade in hides and skins has developed in the air-dried product because (*a*) it is quicker, cheaper and easier under native conditions, (*b*) salt is not widely available for salting and pickling, (*c*) the transport charges on air-dried hides and skins are less than on salted or pickled ones, and (*d*) no special railway trucks or steamer storage are required. Salting and pickling will, therefore, not be considered in detail though it is perhaps wise to point out for the benefit of those tempted to use these two methods that, unless there is a sufficiently large quantity prepared, it will not be worth the while of the exporters to handle and develop markets for these products even if the regular shipping lines were prepared to carry small consignments, which would need special storage.

Exported air-dried hides are commonly classified into "sun-drieds" and "shade-drieds," according to the method of air-drying employed, though it would probably be more correct to classify the second group as "suspension-drieds." The difference in the methods of air-drying will be apparent from the descriptions given later, but it is first necessary to describe the preparation which should be given before the actual drying takes place and to emphasize that cleaning and drying should be started as soon as possible after removal from the carcasses. Delay at this stage may affect the tanning value very seriously.

Preparation of Hides and Skins

As already stated hides and skins take up large numbers of micro-organisms from their surroundings and their composition favours the rapid development of these micro-organisms. At the time of slaughter and flaying, hides and skins often become smeared with blood and contaminated with dung, and these substances are also excellent media for encouraging the growth of micro-organisms. Therefore the first thing to be done after removing hides and skins from animals is to lay them flat on a concrete floor and scrub them thoroughly on both sides with a broom and plenty of water. Where water is scarce, and unfortunately this is a frequent occurrence in East Africa, what water can be spared should be used at this point for washing the hides and skins free from blood, mud or dung. The sooner blood is washed off the better, because it is then more easily removed, less water is required for the purpose, and its removal reduces the rate of bacterial development.

After washing, hides and skins should be cleaned of surplus flesh and fatty deposits. This is done in many ways to-day, many of them being very undesirable, but in order that the undesirable methods shall not be used all are described and commented upon. Hides and skins may be given:

(*a*) no treatment at all and lumps of meat and fat are left on at the time of drying;

(*b*) they may be hung on a nail and the flesh and fat removed by a native pulling on the particular portion involved with one hand and cutting it off with a sharp knife held in the other hand;

(*c*) they may be laid flat on the ground and treated as in (*b*);

(*d*) they may be laid flat on a table and the surplus meat cut off with a sharp knife;

(*e*) they may be laid flat on a table and fat and meat removed with a sharpened piece of metal shaped rather like the blade of a hoe;

(*f*) they may be stretched in a frame ready for drying and then have the surplus fat and meat cut off as in (*b*).

The first method is wrong because excessive amounts of fat or meat retard drying, the fat cells may be ruptured and the liberated fat soak into the conum, the excess of fat may go rancid and the weight of the hides and skins are fictitiously increased. On the other hand, if only a little fat and meat are left on the hides and skins after flaying and no proper facilities for cleaning are available, it is much better to leave the little meat and flesh on the hides and skins rather than remove it but gouge the substance in doing so by the niggling strokes of a sharp knife. The second method of removing flesh and fat after hanging up the hides and skins cannot be condemned too severely. To get the meat off, the knife blade has to be directed towards the hides or skins and gouging, cuts and even holes are bound to result. The third method, where the hide is laid on the floor, is very little better and should not be employed. The fourth method is a step forward but again suffers from the defect that gouging is inevitable unless the cleaning is done extremely carefully but, under practical conditions today where the labour is often of the casual type and the day's task is so many hides or skins, the native operator has neither enough time nor enough interest in his work to be sufficiently careful. Often, too, the tables are not smooth but one board juts up slightly with the result that the stroke of the sharp knife is suddenly arrested and a cut or hole is made in the hide or skin. The fifth method is slightly better than the fourth but introduces the same opportunities for gouges, cuts and holes to occur. The sixth method is also not very satisfactory and leads to gouging, cuts and holes.

If methods four or five are contemplated, it is essential to see that the table surface is absolutely smooth. The natives employed should be in regular employment and always used for this work, and should be given enough time to do the work carefully. A system of bonuses for hides and skins cleaned without gouge marks, cuts and holes might act as an incentive to better workmanship.

A method which I think could be introduced with advantage in establishments regularly carrying out this work of cleaning and preparing hides and skins requires a "beam" as used in tanneries for fleshing hides. Essentially this consists of a convexly curved surface, sloping to the ground at an angle of 30° and of such a length that the upper end reaches half-way up the thighs of the operator. The "beam" and its method of use are shown in Figures 5 and 6. The hide is placed over the beam and the operator, holding the upper end firmly between his leg and the top edge of the beam, shaves the surplus flesh and fat off with a double-handled flat knife about 20 in. long in the blade. By keeping the knife-blade nearly parallel to the "beam" sufficient surplus flesh and fat is taken off and the dried product is very attractive. It is not suggested that the object should be to remove all fat, meat and connective tissue, as to do so would probably lead to gouge marks and cuts unless the operator were very experienced and, in any case, the tanner is better equipped to do this.

When hides and skins are cleaned of flesh and fat they should have a series of holes cut round their edges at convenient points for stretching out the hides or skins to their fullest advantage. The holes should be made as near the edge as possible and up to 40 holes may be required according to the size of the hide or skin. The easiest way to do this is to fold the hide or skin, hair-side downwards, over a rounded piece of wood and to make the hole by cutting with a sharp knife. The tail should be cut off and the shanks trimmed off short (i.e. above the level of the hock or knee) and any irregular portions removed from the neck, belly and legs.

Having taken the trouble to wash and clean the hides and skins in the above manner no one would then peg it out on the ground and sun-dry it, so that the only alternative is to dry it by suspension. If the hides and skins have picked up sand, dirt, blood or any other undesirable contaminant during cleaning they should be given a quick wash before being tied to wooden frames, which are slightly larger than the hides or skins when the latter are stretched out flat. Four pieces of rope should be used, two tied to holes in the neck and to the top of the frame and one to either front shank and to each sidepiece of the frame. This sites the hide or skin correctly in the frame. A long piece of rope is then threaded through each hole in turn and passed round the frame and through the next hole in the hide or skin until the latter is laced firmly, under light but even tension, to the frame and so that no part of the hide or skin touches the frame. The original four fixing ropes can then be removed.

Sun-drying Hides

The normal method of sun-drying hides and skins, which was used almost exclusively in the past and is still, unfortunately, too prevalent to-day, consists of pegging out the hides or skins on the ground, hair-side in contact with the ground, and leaving them exposed to the sun until dry. Usually the hides and skins are not cleaned of mud, dung or blood, are not fleshed and may even be smeared with dirt deliberately to hide blemishes. Sometimes they are not pegged down but are roughly stretched out and allowed to dry with many crinkles and folds. Such hides or skins furnish the "sun-drieds" of commerce and it cannot be emphasized too strongly nor too frequently that this method is most undesirable and may cause considerable damage to quality and consequently reduces the financial returns to the industry. The purchase of sun-dried hides and skins by a tanner is largely a gamble because he will probably lose at least 10 per cent and possibly more than 25 per cent in the lime-yard. In fact, sun-drieds are regarded as the bane of a tanner's existence.

The main reasons why the sun-drying of hides and skins cannot be condemned too severely are:—

(*a*) Because of the method of exposure to the sun, the outer layers of the skins and hides quickly become desiccated and "casehardened" so that the removal of moisture from the inner layers is greatly retarded. This moist central layer is thus able to support bacterial action for some time, with the result that the internal fibre structure is damaged, making the substance more loose and porous. In some cases this damage may be so extensive as to cause such complete decomposition in the central layer that when the hides and skins go into the lime pits the two outer layers become completely separated—a condition referred to in the trade as "blister." Unfortunately the extent of this damage cannot be assessed in the dried state and only makes its appearance during passage through the tannery.

(*b*) Where the hair-side is in close contact with the ground, drying is retarded and bacterial damage occurs which shows itself in the tannery in eroded patches in the grain. Often this trouble is not visible in the dry state though, where it is more extensive, "hair-slip" may develop and these hairless patches are visible. This kind of damage is referred to in the trade as "taint."

(*c*) The strong sun may cause the fat cells to swell and burst and the fat to penetrate into the hide substance. When this occurs the penetration and fixation of tanning is greatly retarded and gives rise to "dry-spots" or "grease-spots" in the finished leather.

(*d*) Lipases, produced by contaminating micro-organisms, have greater opportunity to act on fat when it is spread through the hide substance than when retained by the fat cells. Also, the spreading of fat, following rupture of the cells, exposes a greater area to oxidation. Thus hydrolytic and oxidative rancidity develop in sun-dried hides.

(*e*) Over-drying in the sun causes changes in the hide fibrils, which reduces their capacity to re-absorb water and their ability to resume their normal crinkly character. These changes reduce the value of the final leather.

(*f*) Over-drying in sunlight converts the interfibrillary proteins and any collagen degradation products, caused by putrefactive bacteria, into insoluble cements which still further interfere with the quality of the leather.

(*g*) A thin parchment-like layer forms on the flesh side which will not swell in water, gives difficulties during fleshing, retards penetration of water, lime and tannins into the hides or skins and so affects the final leather quality.

Suspension Drying

By this term is meant the suspension of hides and skins so that they are stretched lightly under even tension and allowed to dry in such a position that air can circulate freely along each side. This is usually accomplished by lacing them with ropes to a rectangular wooden frame, which should be sufficiently large that no part of the hide or skin lies in contact with the frame. The rope should be tight enough to stretch the hides or skins out flat and preserve their shape but must not be more tight than absolutely necessary, otherwise, as the hides or skins contract on drying their structures will be damaged. Their shape will be distorted if the rope is tighter in one direction than another. Figure 1 illustrates the method of suspension.

Drying may take place either (*a*) in a well-ventilated shed, (*b*) in the shade of a tree or house, or (*c*) by fixing the frames vertically in the ground and drying in the sun. Sheds have been built in many places in East Africa specially for the preparation and drying of hides and skins. These sheds have thatched roofs and expanded-metal sides to protect the hides and skins during the drying period from rain, sun, theft and spoliation by wild animals and to allow free ventilation. Experience in tanneries quickly showed that such shade-dried hides and skins were usually superior in quality and suffered smaller losses in the limeyards than sun-drieds. In fact shade-drying by suspension in properly designed sheds represented a very distinct advance in the preparation of East African hides and skins. The main disadvantage of this system is the cost of erecting suitable buildings at any centre where only a few hides and skins are produced. Because of this disadvantage the Imperial Institute [3] sought an alternative method which would produce hides and skins of equal quality and value. Their experiments, carried out with the help of the Kenya Veterinary Department, showed that shade is not the essential factor but that suspension, so that air could circulate freely all over the hides and skins, is the really important consideration.

As an illustration of these facts it is well to quote a practice sometimes followed, namely, the drying of hides and skins by hanging them over a pole in a shed. Although drying has been entirely in the shade and the hides and skins look perfectly normal in the dried state, they turn out badly in the tannery where it is found that the area dried in contact with the pole is "tainted" and the grain badly damaged.

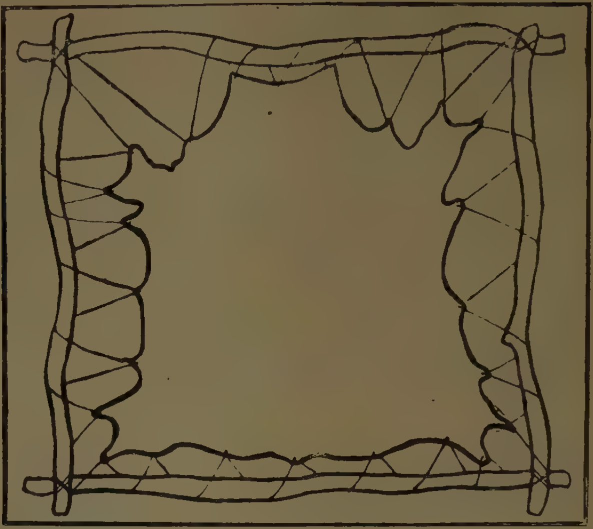

FIG. 1

Hide of good pattern and good trim suspended for drying in a wooden frame.

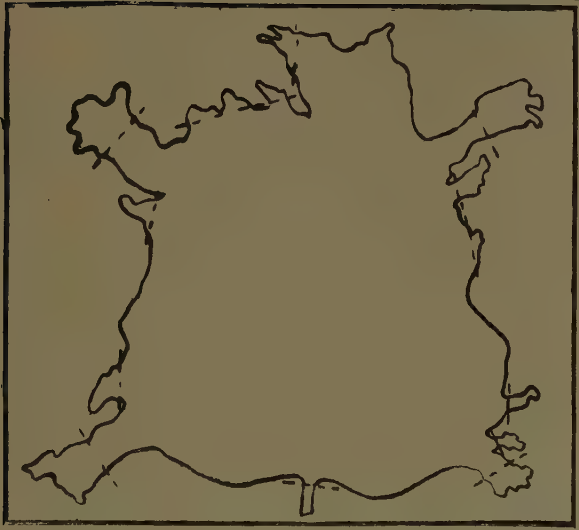

FIG. 2

Hide of bad pattern and bad trim. Dotted lines indicate where hide should have been trimmed.

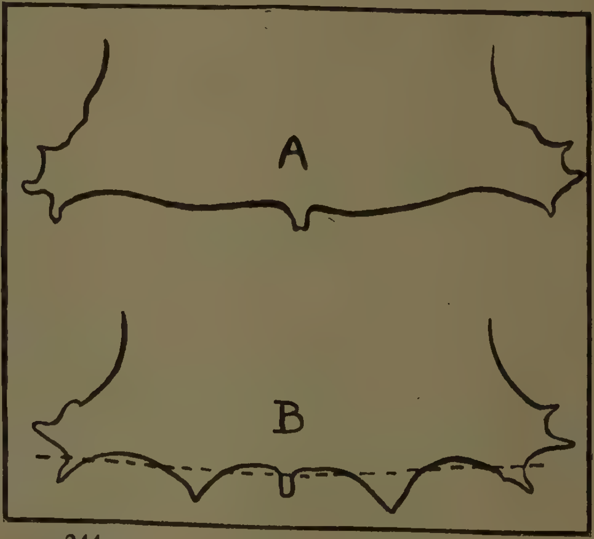

FIG. 3

Posterior outline at A when opening from back of hocks to anus and at B when opening from inside of one hock across udder or scrotum to inside of other hock.

The area in contact with the pole dries slowly because air cannot circulate freely over it with the result that bacterial activity is given sufficient time to decompose the grain proteins. Hides or skins must, therefore, never be hung over poles to dry.

It may also be as well, at this point, to mention the drying of that portion of the hide which covers the hump in Zebu cattle. Until fairly recently it was commonly believed that the hide over the hump had little commercial value. This is definitely not true and care should be taken to see that the bulge due to the hump is dried properly and not in a crumpled position. The easiest way to achieve this is to hang two hides, hair sides towards each other with adequate space for free air circulation between them (12 in.) and to insert a thin stick of such length into the two hump areas that the hump portions are stretched out to their natural shape.

The experiments of the Imperial Institute and the experience of tanners has proved that providing there is some tempering of the sun's force equally good results can be obtained if the hides and skins are laced to a wooden frame and dried in the sun. The Imperial Institute originally recommended that hides and skins should be suspended so that the planes of the hides and skins lay in an east and west direction and at such an angle to the vertical that the rays of the mid-day sun shone parallel to the planes of the hides and skins. The object being, of course, to expose the hides and skins as little as possible to the sun's direct rays. Excellent results have since been obtained in East Africa by suspending the hides and skins vertically, with their plane in an east and west direction. In this method the mid-day rays of the sun strike the hides and skins obliquely but it appears that this does not affect their quality sufficiently to justify the extra trouble required to maintain their planes parallel to the sun's rays at its meridian.

Suspension drying in an east and west direction (*a*) removes any difficulties about suitable shade-drying buildings; (*b*) allows any native to carry it out at his house without having to hand his hide or skin into the keeping of the staff of a shade-drying shed; (*c*) eliminates delays before cleaning and suspending, such as must occur if the producer lives some distance from a shade-drying shed and has to carry his hide a long distance in the hot sun; (*d*) fits easily and economically into the conditions of native and European farmers; and (*e*) is a very valuable method for assisting drying in sheds at the coast or wherever the atmosphere is very moist and a long period is required for drying in sheds. But suspension drying is not intended to replace shade-drying in sheds where the latter can be erected and run economically.

Suspension drying, whether in the shade or the sun, is most strongly recommended for universal adoption throughout the whole of East Africa. A very much more reliable and valuable article is produced than by sun-drying on the ground because (*a*) drying proceeds more uniformly and there is less risk of blister; (*b*) the fibrils are not damaged so severely; (*c*) the fat cells are not ruptured; and (*d*) hair slip and taint are reduced to a minimum. Tanners have learnt by experience that with such hides the losses in their lime-yards may be only 2 per cent and probably not more than 10 per cent and so are prepared to offer prices which are approximately 33⅓ per cent more than for the same grade of sun-drieds. The quickest method of improving the export value of the hides and skins industry would be to extend the method of suspension-drying to as many hides and skins as possible.

The period required for drying by the suspension method will vary according to season and the humidity of the atmosphere—less than a week being required in the dry season up-country and up to 12 days in the wet season. In the wet state hides and skins have a milky opaqueness but take on a yellowish translucence when dry. When the opaqueness has disappeared the thicker neck portions and those pieces under the ropes should be felt. If these feel dry the hides and skins can be removed from their frames.

The hides and skins should then be brushed on the hair side to improve their appearance and to remove dust and straws and then folded down the backbone line, hairside inwards. To make their shape more convenient for handling, storage and baling, the belly portions should also be folded inwards. After drying and folding it is a good plan to put the hides and skins in the sun for a few hours, turning them at intervals to make quite sure they are completely dry.

Storage

Hides and skins should be sold to middlemen or exporters as soon as possible after drying. If this is impossible, they should be stored in a clean, dry store where white-ants, rats and other vermin cannot damage them and where there is no possibility that they will become wetted by rain or water. If dried hides and skins become wetted by rain or water contaminating spores of micro-organisms spring to life and much putrefactive damage can be done. It is a good plan during such periods of enforced storage to put the hides and skins out in the sun for an hour or so once a week. This gives the holder an opportunity to examine them to make sure no damage is occurring. Also, if it is expected that they will have to be stored for some weeks before they can be sold, they should be dusted with naphthalene, pyrethrum or derris powder to protect them against damage by hide beetles and Tineid moths. The larvae of these insects damage the grain surface and cause considerable damage to the industry during unnecessary storage or storage in infested buildings.

To protect their hides and skins against such damage the exporters dip all their stocks into a solution of sodium arsenite and re-dry before baling for export or storage in their godowns. This arsenication measure has done much to protect exported hides and skins against insect damage but more care is needed in up-country stores to eliminate all such damage before the hides and skins reach the coast. I am sometimes asked if there are no other preservatives which could be employed instead of arsenic. Soaking hides and skins in ½ per cent sodium fluoride might be, and soaking in saturated (½ per cent) sodium silicofluoride [4] solution before drying is known to be a very useful method and eliminates the need for subsequent re-wetting in arsenic baths. The newer insecticides D.D.T. and Gammexane, have not yet had their exact values for preventing insect damage to hides and skins determined on a wide scale and I cannot make any quantitive recommendations for their use.

SUMMARY

(1) Hides and skins should be removed from carcasses as quickly as possible after death. Knives should be used in this operation as little as possible and all skins should be removed by hand after the initial opening cuts have been made.

(2) Hides and skins should be scrubbed free from blood, dirt and dung immediately after removal from carcasses.

(3) No delay should then be allowed before any surplus fat and flesh are removed and care taken to see that the hides and skins are not damaged by gouge-marks, cuts and holes during this fleshing operation.

(4) Hides and skins should be trimmed of all uneven pieces, long shanks, tails, etc., before drying.

(5) After cleaning, fleshing and trimming, the hides and skins should be washed and suspended in frames to dry.

(6) Suspension drying can be done in specially designed sheds, in the shade of a tree or house or vertically in the sun.

(7) After drying, hides and skins should be folded and sold as quickly as possible.

(8) If storage has to take place before sale, care should be taken to protect them from rain or moisture and to prevent damage from vermin, white-ants, hide beetles and Tineid moths. Dusting with naphthalene, derris or pyrethrum powder is advocated for reducing insect damage during short storage periods up-country.

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(*To be continued*)

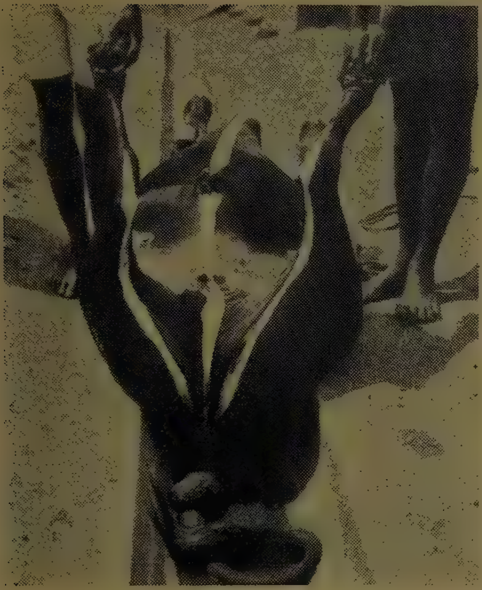

FIG. 4
Position of correct opening cuts.

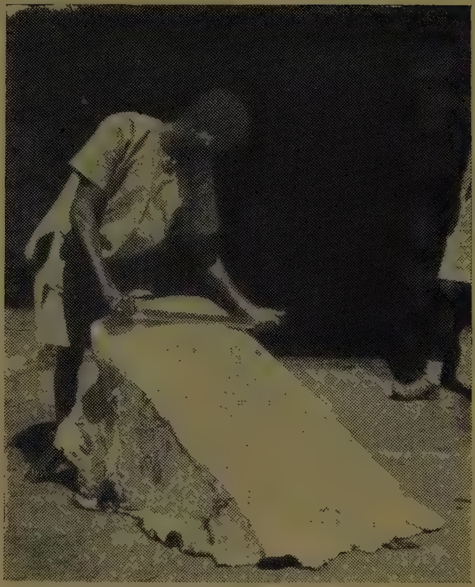

FIG. 5
A native removing surplus flesh and fat from a hide stretched over the beam shown in Fig. 6.

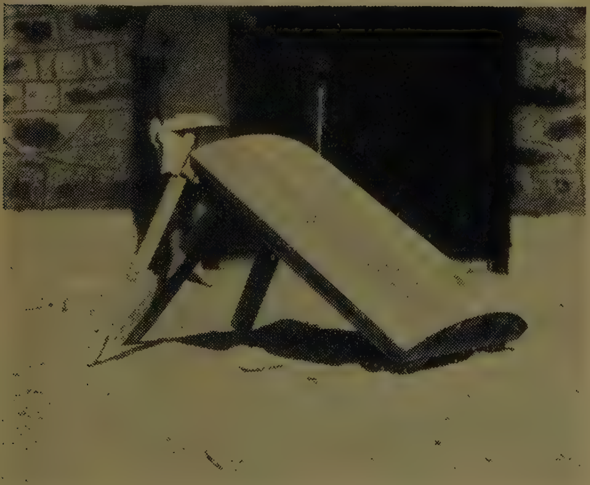

FIG. 6
A cheap locally constructed "beam".

Sisal three years old after a first cutting. The plants are spaced 50 cm. apart in the row. Note tendency of large plant to dwarf its neighbours.

Cutting sisal spaced three metres apart between rows. Even at this spacing working space is barely adequate if light cutting is practised.

Sisal spaced two metres between rows. Note heavy cutting needed to enable cutters to work.

To face page 247

OBSERVATIONS ON THE SPACING OF SISAL

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The early field trials on the Mlingano Sisal Experimental Station showed that of all the factors affecting sisal yields, spacing, in so far as it determined the density of plants, was by far the most important. As the population of plants per unit area increased so did the total tonnage of fibre obtained during the life cycle. A paucity of plants, such as 1,500-2,000 per hectare, only yielded about five to six tons against 30 tons reaped from 10,000 plants per hectare. Intermediate populations likewise yielded according to plant number. The total fibre yield and the longevity of the sisal were closely and positively correlated with plant density.

It is not proposed to deal with the results of spacing trials in this article beyond pointing out the profound influence of plant density upon yield. The optimum density will vary according to climatic and soil conditions and no hard and fast rule can be laid down beyond stating that one aim should be to have as many plants as possible without seriously impairing the development of the sisal. Within reason, the more favourable the growth conditions are, the greater the density may be, and, conversely, the poorer the conditions the lower the plant population.

The proper approach to determining any spacing for an estate, or section thereof, is first of all to decide how many plants the land will carry satisfactorily. Having reached this decision the actual espacement to be adopted should then be considered. Frequently these two factors are dealt with in the wrong order. For example, should a density of 5,000 plants per hectare be settled upon, then the question whether the spacing should be 2 x 1 m., 2.50 x .80 m., 4 x 1 m. x .80 m., or any other variant giving 5,000 plants, should be answered afterwards.

Under Tanganyika conditions, there is no such thing as an ideal spacing for sisal. Each of the popular systems suffers from one drawback or another. Either the density is too low, or the plants are too close, or else there is insufficient room for labourers to work or tractors to operate. The difficulty of satisfying these conflicting desiderata is amplified as the density becomes greater. At the higher densities of over 5,000 plants per hectare, the grower is usually driven to using the double-row or "Sumatra" system.

Although plant population is an extremely important matter, it is by no means the only factor which has to be considered. Fetish adherence to density could lead to wholly impracticable spacings. Another aspect of equal significance concerns the *ease of management* of sisal fields and it might so happen that it would be best in the long run to compromise between these two factors by sacrificing plant density to some extent for the sake of management. If the spacing were such as to debar adequate cultivation or adversely influence cutting, then it would obviously be wrong.

In some respects sisal may be regarded as an awkward plant to cultivate because not only are the leaves armed with sharp terminal thorns but many of them occur horizontally in whorls about ground-level due to the plant having a short stem or bole. If the leaf tips of adjacent plants are close or overlap from all directions then a field of sisal becomes impenetrable except just after cutting; likewise weeding is severely hampered during the young stages when cultivation has the most beneficial effect. Working space is clearly one requisite and it suffices if such space is provided in one direction only, e.g. between the rows. Unfortunately wider spacing betwen rows reduces density unless the plants are closed up within the rows, and here a limit is imposed by the need to avoid overcrowding in the row, Resort may be had to double-row, which in effect is just a partial solution, since working space is furnished between alternate rows only. Incidentally it may be mentioned here that closing up the plants *within* the rows has a greater effect upon increasing density than closing up the distance *between* the rows.

The respective values of single-row and double-row come next for review.

SINGLE-ROW PLANTING

Single-row planting has been popular in Tanganyika almost since the inception of the sisal industry. For many years past 2 x 1 m. (5,000) spacing has been a great favourite, especially on estates formerly under German management. The advantages of single-row lie in easier hand-weeding around the plants, particularly when they are young, removal of bush stumps developing after planting, and control of sucker growth. Another questionable concession to the system is that the stand of plants is more open, giving less risk of damaged leaves through abrasion. But single-row also has numerous defects, especially when high densities are required. 2 x 1 m. spacing is a case in point and may be condemned from many angles. To begin with, the young sisal can only be weeded by hand during the first year or so; thereafter the lower leaves restrict the passage between the rows to some 60 cms. (2 ft.). Thus labourers are obliged to work circumspectly in order to avoid damaging the plants (and themselves); a tedious process which they commonly shun. There is also a strong tendency to pile weeds, often with clods of earth, into the centre of the 2 m. path, resulting in the formation of ridges. These ridges are objectionable because they hinder drainage or are conducive to erosion down the furrows, exposing sisal roots.

A narrow spacing between the rows dictates severity of cutting due to the proximity of the tips of upper leaves belonging to opposite plants. These are usually about eye-level, restricting the passage of workers. Hard cutting must be practised at all times; in particular the initial cut of young sisal has either to be too severe or else it has to be delayed until the plants are bigger. All these features are undesirable. It will be seen that a narrow space between rows of sisal has little to commend it under any circumstances. It is interesting to reflect that before the last war there was a common impression in local circles that the Germans were efficient sisal planters, but their adherence to 2 x 1 m. spacing goes to show that they were not immune from making mistakes even in sisal planting.

Supposing very strong reasons exist for planting sisal in single rows, then the lower the density the more the advantages of the system are apparent. 3 x 1 m. (3,333) or any wider spacing is satisfactory in several respects in that it allows access during the immature stages of the sisal, cutting may be regulated, and small tractors can be used after each cutting. Generally speaking, however, a density of 3,000 plants is too low for the majority of estates in Tanganyika though it is more applicable to conditions in the Kenya highlands. When seeking densities of 4,000 or 5,000 plants, spacings of 3 x .80 m. (4,158) and 2.50 x .80 m. (5,000) are preferable to the more usual 2.50 x 1 m. or 2 x 1 m. systems because they afford greater freedom for work. A width of 2.50 m. is certainly an improvement upon 2 m. though it does not meet fully all the needs of the sisal grower.

The next point to be considered is the closeness of planting *within* the row. It is often contended that excessive leaf abrasion results from having the plants too near to each other. Manifestly, if leaf rubbing is to be eliminated, 2 m. or more would have to be interposed between plant centres, thereby reducing the density to a low order. It is hard to conceive a worse spacing than 2 by 2 m. (2,500) which besides giving a low density precludes ingress from any direction whatsoever; in addition the plants are rather exposed. When the plants are at 1m. intervals, leaves growing out more or less in line with the row intersect at a point about one-third down the blade of the leaf from the tips; by closing the ranks still further the point of intersection occurs in the region of the middle of the leaf where it happens to be more rigid. In the latter instance rubbing is more likely to occur on the edges of the leaves than upon their surfaces. It must also be remembered that high wind, causing newly unfurled leaves to flap against the tender white tissue of the central spike, is another source of leaf marking. Consequently it might be said that much of the criticism about close planting in the row may be discounted on the score of rubbing. At the same time if sisal is planted too closely then overcrowding will force alternate plants to lean outwards on both sides of the row besides, causing buckling of overlapping leaves. A more serious consequence is a tendency for alternate plants to be dwarfed through the overshadowing of their bigger immediate neighbours. The minimum distance depends to some extent upon the size of the plants though it would appear to be about 70 cm. for large sisal.

DOUBLE-ROW PLANTING

The double-row system of planting sisal overcomes many of the disabilities pertaining to the single-row system but it too has snags. Double-row is not looked upon with any favour by growers as a body and the usual complaint levelled against it is that "the cutters do not like it". Basically there is little to support this argument and it is rather extraordinary that criticism of a similar nature is rarely heard about the incomparably worse conditions for the cutter to be found in congested sucker-regenerated fields.

A valid objection to the double-row method is that the pairs of rows are difficult to weed when the sisal is young. In the event of a shortage of labour or a prolonged period of wet weather, the weeds get out of control and the sisal becomes rather overgrown with grasses and possibly light bush. On most soil types the secret of managing double-row sisal lies firstly in having a perfectly clean start on stumped land, preferably prepared by mechanical means, and secondly to maintain the pairs of rows in an absolutely clean condition for as long as is practicable, usually about one year. Planting double-row on imperfectly prepared land means courting difficulties at the later stages, particularly during the two years preceding the first cut. The object of keeping the pairs of rows thoroughly clean is to check the weeds to such an extent that they have the minimum nuisance-value by the time the young sisal is large enough to prevent hand work and yet can exert shading effects. It should be noted that the above injunctions to clean-weeding apply mainly to the narrow strips of land occupied by the pairs of rows; it is not always essential to keep the entire area clean-weeded.

It is especially important for double-row sisal that the first cutting should be reasonably early although this is advisable for all sisal whatever the spacing. Early cutting affords an opportunity to remove weeds and suckers which have sprung up during the previous twelve or eighteen months. If cutting is unduly delayed desuckering may prove an expensive operation. Once the initial cut has been taken, upkeep of the pairs of rows presents few difficulties because the lower whorls of sisal leaves are no longer very close to the ground and the task of removing weeds and suckers is unlikely to be in arrears for longer than the ordinary cutting cycle of twelve months.

Turning to the problems of cutting double-row, such undoubtedly exist though they are apt to be exaggerated. The cutter is confronted with the tip thorns, not only of the plants in the row being cut, as in single row, but also those of diagonally opposite plants which are not quite so easy to snip off with the knife. Perhaps the most disliked part of cutting double-row is the necessity for the cutter to stretch his arm around the plant to cut the least accessible or innermost leaves. Good field supervisors pay heed to this point. On the other hand the cutter has ample room between the pairs of rows to bundle and carry out leaf and consequently is spared from puncturing his posterior or scratching his limbs on the next row of sisal. Therefore it could be argued that double-row is more of an aid than a hindrance to sisal cutting.

Sometimes it is averred that double-row planting leads to greater variation in plant size than single-row. This might conceivably result at high densities should poor and irregular planting material be used, but given good plants a wide disparity in development would be unlikely since the spacing employed has a comparatively very slight effect upon the growth of sisal during its first year in the field. Any variation that exists may appear more noticeable owing to the juxtaposition of the twin-rows.

It is frequently assumed that double-row must of necessity lead to more leaf abrasion than single-row though this is a moot point. Actually the extra number of leaves in contact with those of the opposite row is not very great, especially if the rows are staggered. The interlocking of the leaves imparts a rigidity to the mass and the double rows become more efficient windbreaks, protecting parallel pairs of rows.

The chief attribute of the double-row method is that the spacing may be so arranged to make access always possible without diminishing plant density. It will be readily appreciated that access implies ease of management and that a combination of this factor with high density is of no small advantage to the grower. Maintenance of bearing areas at once becomes completely independent of cutting and the carrying out of field work may be logically and expediently timed according to season. Furthermore, access enables obnoxious weeds like the Buffalo Bean (*Mucuna puriens*) or acacia thorn trees, to be controlled or eradicated. In addition the removal of senescent or rotting plants in order to reduce breeding grounds for the sisal weevil (*Scyphophorus acupunctatus*) becomes a feasible proposition, while poles may be cut back to preserve leaf.

Another attraction of the double-row system of planting is that it serves the aims of both sisal cultivation and soil management. This is tantamount to an overriding consideration in its favour. The preservation of soil fertility is a major aspect of sisal-growing especially on the poorer sandy soils near the coast where it is sometimes inadvisable to divorce the soil from the indigenous bush-growth or other vegetation providing a soil cover. Only the strip occupied by the pair of rows need be stumped, burning before planting may be avoided and in its stead the trash and plant residues may be piled in the intervening space separating the pairs of rows. Subsequently the bush-growth may be controlled by periodical cutlassing which once again is not contingent upon cutting the sisal.

At Mlingano the growing of cover crops in single-row sisal proved most unsatisfactory, but with double-rows widely spaced it has been possible to establish on an experimental scale a neat leguminous cover of *Glycine javanica* without unduly affecting the progress of the young sisal. The centre of the pairs of sisal rows were weeded for as long as possible after planting, the cleaning of 50 cm. on both sides being continued.

Sisal is a crop which is grown by the square mile rather than by hectares or acres and it is patent that its cultivation should be mechanized wherever possible. Under high plant-densities double-row planting is obviously a pre-requisite for mechanical cultivation. The additional width between the twin rows can be on a scale that will allow the passage of tractors and implements almost at will irrespective of the development of the sisal. It is also true, of course, that double-row planting does not entirely dispense with the need for manual labour, yet it helps to reduce the area which has to be hand-hoed up to as much as a half. Work of this character is only necessary for the first eighteen months to two years and it progressively gets less as the sisal grows larger. The value of the double-row system is exemplified in areas where tall grasses like *Panicum maximum* grow luzuriantly during the rains. Although the state of the land when it is wet may prohibit the use of tractors, mechanized equipment will effectively master such growth during dry seasons, when the conservation of soil moisture is most vital, leaving an excellent mulch of dead grass covering the soil.

Spacings of 4 × 1 × 1 m., or 4 × 1 × .80 m., giving plant densities of 4,000–5,000 per hectare respectively have been found eminently satisfactory in practice. The last figure refers to the distance between plants in the row and it is preferable to stagger the twin rows. One important feature of these spacings is the four-metres working space separating the pairs of rows, which is generally adequate for most purposes. A wider distance apart would only be justified when plant population was of less importance and tractors and trailer could be employed for collecting the leaf after cutting such as is practised on an estate in Kenya.

When a field of double-row sisal is due for replanting, plants of the next cycle may be sited in the four-metre strip, which should be cultivated thoroughly, and the old boles can be split and left to rot *in situ*. The interplanting of young sisal amongst bearing sisal is not recommended even with double-row.

The foregoing discussion should help to emphasize that the topic of spacing is of paramount interest to the sisal grower. Such an important question should be resolved in the light of local conditions and their bearing upon plant population and field management. The merits and faults of both single-row and double-row have been examined without bias. On the whole, double-row shows up to greater advantage largely owing to its versatility, especially in regard to protecting the soil, and it would be a prudent measure, not only from the angle of mechanization, if this system were more generally adopted on sisal estates in East Africa.

Dr. H. H. Storey, at present Chairman of the East African Industrial Research Board, has been elected a Fellow of the Royal Society for his outstanding research into plant virus diseases.

Dr. Storey is the first scientific worker in the East African territories to receive this distinction. He carried out his work at the East African Agricultural Research Institute at Amani, where he was Plant Pathologist from 1928 to 1941, and on several occasions Acting Director and Editor of this Journal.

GROWTH AND BEARING HABITS OF COFFEA ARABICA IN KENYA AND IN SOUTHERN INDIA

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(*Received for publication on* 21*st January*, 1946)

The growth and bearing habits of arabica coffee in Southern India have recently been described by Mayne [1]. Since detailed observations have been made in Kenya at the Scott Laboratories, on the growth and flowering cycles of coffee for the last three years and, in addition, the morphology of the bud and branch systems has been studied, it is of interest to compare the results obtained so far with Mayne's observations.

CLIMATES

The climates of the two areas differ considerably. The rainfall is higher in Southern India, ranging between 80 and over 100 inches per annum, whereas in the main Kenya coffee areas it lies between 25 and 60 inches in normal years. The temperatures are also perceptibly higher and have a wider range. They are roughly comparable to those expected between 3,400 to 3,900 ft. in Kenya where the main coffee areas are between 5,200 to 5,800 ft.

The rains, as in Kenya, are the result of the inter-action of the two monsoon currents. However, as the Indian areas are about 12° N. of the equator, the duration of the south-west monsoon is short and the rains due to the rainfall belt moving northwards merge into the rains due to its return southward. There is thus practically only one rainy season, the first half associated with the onset of the south-west monsoon, and the second half with the onset of the north-east monsoon. The Kenya coffee areas, on the other hand, are just south of the equator with the result that there are two distinct rainy seasons, the "long" and "short" rains, an interval of about seven months separating their maxima. There is, thus, a single dry season in Southern India instead of the two experienced in Kenya. It starts in December and lasts until the end of March. It is a period of clear skies, the first part being the coldest period of the year, whereas during the second half the temperature ascends to a maximum at the onset of the rains. With the rains, the temperature falls rapidly at first and then more slowly. There is a slight rise in September and then again a fall until the dry season commences.

The rains are at their maximum in July and there is no distinct break between the first half associated with the south-west monsoon and the second half associated with the north-east monsoon.

GROWTH OF THE COFFEE BUSH

According to Mayne, the principal resting period for the coffee bush is in the dry period from December to March with a minimum in December and January. As the temperature rises in February and March, even though no rain has fallen, growth commences. Approximately nine days after the first substantial shower terminating the dry season has fallen, the main flowering occurs. With the blossom showers a rapid vegetative development takes place and the greater part of the annual shoot growth is initiated. This period is short, the growth rate declining to almost nil during June and July. Vegetative growth commences again in August and continues throughout September and October. In years of heavy crop the first growth period ceases earlier and the second is less marked. With the cessation of the rains in November, the growth rate falls to a minimum and the crop ripens. During September, the first externally visible indications of the flower buds can be seen.

The sequence of events in the growth cycle in Southern India is seen to have very definite resemblances to those normal in Kenya and to occur approximately during the same months in spite of the fact that there are two dry seasons instead of one in the latter country. In the main Kenya coffee-growing areas there is a hot, very dry and sunny period during January and February, when growth is at a minimum. The limiting factor is soil moisture, since watered trees at this time will give maximum growth, once recovery from the previous crop has occurred. Frequently there is a short period of rain towards the end of February, the so-called "grass rains," when a short period of rapid growth may occur. The main period of rapid vegetative growth commences with the onset of the long rains and the greater part of the annual growth is normally produced at this time. The main flowering usually occurs at the onset of these rains or subsequent to the preceding grass rains if these occur.

The long rains are followed by a cold, cloudy, dry period during which vegetative growth is extremely slow. The climatic factors causing this depression in growth are apparently multiple. In 1942, when the long rains were good, growth fell to a minimum before the rains ceased. This fall occurred as the cloudiness and the associated lower temperatures became more marked. The partial regressions of these climatic factors obtained from data from watered trees in 1943, a particularly favourable year for such studies, would only partially account for this fall in growth rate and it is suggested that leaching, especially of soil nitrates, may have been responsible. In 1943, the long rains were poor and soil moisture was the main limiting factor as shown by the growth of the watered trees; low temperatures and cloudiness were secondary factors. As the short rains approach, the temperature rises somewhat and there is less cloud. There may be a rise in growth in response, but it is only slight until the short rains commence, when there is a minor period of growth. There is normally, at this time, a ripening crop on the trees and undoubtedly this is the main reason for the minor nature of this growth period. The onset is also somewhat cooler than the onset of the long rains, although the end is warmer than is the case with the latter. There is usually a small flowering during these rains, the inflorescence buds first becoming visible in August to September.

The minimum growth period during the rains in Southern India is interesting. Mayne draws attention to the apparent antagonistic effect of crop development on vegetative growth and points out that during the periods of maximum fruit growth, vegetative growth is minimal. There are two periods of rapid fruit development, the first following the rapid growth associated with the onset of the rains and the second after the second period of vegetative growth when the rains cease and the fruit ripens. During the two growth periods, fruit growth is slow. In Kenya, the depressing effect of crop on vegetative growth is well known, but there is little to suggest that it has differing demands during its stages of development. Observations of watered trees bearing a fair crop in 1943 showed a gradually decreasing growth with time as the crop matured, when temperature and radiation effects were removed statistically. It would seem likely, since at the time of the June-July minimum rainfall is very high, that leaching of soil nitrates may be the cause, as it may also be in Kenya following good long rains. The minor growth period in August to November may be due in part to the less heavy rainfall in this period causing less leaching and also perhaps to the sunnier weather at this time. A comparison of the various climatic and growth periods and the possible controlling factors in Kenya and Southern India is set out below:—

SOUTHERN INDIA

1. December to March: Dry and sunny, at first cold, later hot. Growth minimal, higher during hot period. Crop picked in November to December; flower bud differentiation later.

Controlling factors: Dryness with low temperature at first as a subsidiary.

2. March to April: Onset of rains. Hot, relatively sunny. Growth ascends to maximum for the year, flowering occurs.

Stimulatory factors: Moisture, radiation and heat.

3. June to July: Maximum rains. Cloudy, temperature falling. Growth falls rapidly to a minimum.

Controlling factors: Leaching ? Decreasing temperatures and cloudiness are important subsidiary factors.

4. August to November: Second half of rains. Onset of north-east monsoon. A second but minor growth period.

Controlling factors: Less cloud and less leaching may produce the increased growth, whereas low temperatures and developing crop and still some leaching and cloudiness may account for its less marked nature.

KENYA

1. Mid-December to mid-February: Dry, sunny, hot. Growth minimal. Crop picked in November to December; flower bud differentiation in January and February.

Controlling factor: Dryness.

2. End of February (grass rains) to March: Onset of rains. Hot, relatively sunny. Growth ascends to maximum for the year; flowering occurs.

Stimulatory factors: Moisture, radiation and heat.

3. April to October: At first maximum rains with temperatures falling and increasing cloud. Later dry, cloudy and cold; less cloudy and warmer towards the end. Growth falls rapidly to a minimum, sometimes before the end of the rains. Some flower-bud differentiation.

Controlling factors: Leaching in years of good "long rains"? Dryness later and also immediately after poor long rains. Low temperatures and cloudiness.

4. Mid-October to mid-December: Short rains (onset of north-east monsoon). A second but minor growth period. A small flowering.

Controlling factors: Soil moisture, higher temperatures and less cloudiness, but minor character accounted for by ripening crop and also possibly a denseness of vegetation on tree.

FLOWERING

In India, "a single blossoming in late March or early April is usual over a large coffee area. In all districts poor rain may cause several blossomings over a period of a couple of months and this usually results in poor crops." In the main Kenya areas the principal flowering usually occurs at the onset of the long rains or subsequent to the so-called "grass rains" in February which often precede them. Short-rains flowerings are, however, common and in some districts are regular in occurrence, and multiple-stem coffee is liable to to produce a short-rains flowering. The development of these flowerings is probably partially dependent on the short-rains growth of the previous year. The minor character of the second growth period in India and the fact that it is followed by a long period of slow growth during which determination and differentiation of the flower bud occurs, possibly explains the absence of a counterpart to our short-rains flowerings. Further, the wetness of the minimum growth period between the two maxima possibly inhibits the development of flower buds at this time.

A series of experiments in Kenya has shown that determination of the flower bud (the point in the development after which it is no longer possible to make a reproductive axis change to a vegetative one) occurs during the period of minimum growth during the months of June to September, between the two growth periods, and again during the second but shorter period in January and February. Some of the grass-rains and long-rains flowerings are differentiated during the first period. In India, Mayne states that the first indications of axillary bud differentiation occurs soon after the crop has been picked, so that determination apparently occurs somewhere about November to January during a period of minimum growth, as is the case in Kenya. Flowering is stated to occur approximately nine days after the first substantial shower, and it thus apparently develops more rapidly than is normal here, where up to fifteen days may elapse. However, particularly strong flowerings have been observed to follow more rapidly, in as short a period as nine days and since in India there is usually only one large flowering, this might explain the apparently more rapid development.

Another possibility is that the more rapid development is due to the higher temperatures, which are considerably higher than in Kenya at the time of the development of the main flowering.

GROWTH MORPHOLOGY

In spite of the general resemblances between growth periods and flowering observed above, the form of the growth itself in India would appear to differ considerably from that usual in Kenya, as is shown by the following summary from Mayne's article. The form of tree is almost universally of the single-stem type and is usually topped first at 3½ ft. and then again at 5 ft. when a new vertical has formed. During the course of time, the lower primary shoots die off and old plants frequently consist of only three or four primaries near the top, each bearing a confused tangle of secondary, tertiary and higher-order laterals. Mayne states that secondary laterals on primary shoots are of two kinds. Under certain circumstances, which probably involve a high degree of vigour, lateral buds in the axils of the youngest pair of leaves develop along with the main branch. These give rise to paired secondaries contemporary with the main shoot beyond the node at which they originate. These pairs of secondaries rarely, if ever, develop at the basal nodes of primaries and there is usually a length of some nine or ten nodes before this secondary growth develops. Mayne believes that such laterals should be regarded as true secondaries. On the other hand, a second type of secondary growth arises more generally from the basal nodes of the primaries during the year these nodes are bearing a crop, or during the following year. He regards these as "developing from adventitious buds in the axils of the leaves" and considers that they should not be classed as true secondaries, although they are always known as such by planters. The future development of the two types differs markedly. The first produces flowers and fruit but rarely further branches and after a time dies off and disappears. The second type develops in exactly the same way as a primary, producing flowers, paired laterals, and further adventitious shoots.

Kenya experience appears to throw some light on the morphological mechanism of the production of these two types of secondary branches. Before proceeding further, it will be necessary to consider the axillary bud system found in *Coffea arabica* [2]. The axillary buds borne in the axils of the leaves are arranged in a series instead of singly as in most plants. For convenience these have been designated by the first six letters of the Greek alphabet, starting with the bud nearest to the stem and proceeding outwards and downwards towards the petiole. Thus, the first and largest bud in the series and the one closest the stem is referred to as the alpha bud, whereas the sixth member of the series which is the smallest and the nearest to the petiole is referred to as a zeta bud. It would appear likely that the origin of the series is from a suppressed axis originating in the axil of the leaf, the beta to zeta buds being really secondaries, tertiaries, etc., on this original axis.

In Kenya, vegetative shoots may be developed from any member of the bud series, but under conditions conducive to flowering the alpha to delta buds develop into inflorescences. Provided they have not passed a certain morphological stage in their development (i.e. are not irreversibly determined as inflorescence buds) which occurs a month or so before flowering when the buds begin to swell rapidly, they can all be changed into vegetative shoots by the removal of the main axis above their point of insertion. The alpha bud may, at times, develop almost as soon as it is formed and produce a vegetative shoot of the same age as the parent axis. These are presumably the shoots Mayne would term "true secondaries." In Kenya, they are not usually developed until fairly late in the growth of the parent axis and since the system of pruning entails the removal of old branches, it is rare for such a shoot to develop its own lateral shoots before the parent axis is removed, though shoots of Mayne's second type do sometimes develop on their lower nodes before the parent axis has been removed. It frequently occurs that such shoots are left attached to the base of the parent axis, the rest of which has been cut off, and in this case they may develop both of Mayne's types of lateral shoots and, in fact, differ little from his "successionary" shoots in behaviour. They never die off as in India unless subject to over-cropping.

Not only do alpha buds sometimes develop soon after initiation, but they may also develop into vegetative axes at almost any later date after a longer or shorter period of dormancy, especially on trees at the higher elevations. Thus a parent axis occasionally develops shoots at its base from alpha, beta, or gamma buds which have failed to flower. Such shoots do not appear to differ functionally in any way from the "successionary" type of shoot described by Mayne. Normally, on shoots where the alpha to gamma buds have flowered, lateral vegetative axes are developed from the lateral members of the bud series. It would thus appear that, in Kenya, transition forms occur between the two types of secondary growth found in Southern India; they are, however, rare. The reason why shoots produced by alpha buds that have not passed through a period of dormancy do not usually produce lateral growths on themselves appears to be that they are usually formed on the younger portion of an old parent axis, so that during pruning they are either cut off together with the younger portion of the parent axis or the latter is cut back to the point of origin of the lateral. In this case, which is of fairly common occurrence, the lateral continues to grow in the same manner as laterals derived from buds that have passed through a period of dormancy and may develop further lateral growths in the same manner. In India, the reason why such laterals derived from alpha buds without dormancy do not normally produce further laterals would appear to be, as Mayne states, that after a time they die off and disappear.

One of the peculiarities of the Southern Indian coffee trees seems to be the tendency for their branches, including even the lower primaries, to die off. One wonders if this is a direct climatic effect perhaps due to a production of vegetation which becomes so thick that the lower branches become starved for light, especially when most plantations are shaded; or whether a disease factor, such as the higher incidence of leaf-rust (*Hemileia vastatrix*), also due to a warmer and moister climate, is at work.

CONCLUSIONS

Although there are considerable resemblances in the cycles of growth, fruiting and flowering in the two countries, there would appear to be some fairly marked differences in the form of the growth produced. These differences are presumably the direct or indirect (i.e. via infectious diseases) effect of the generally warmer and moister conditions. The resemblances in the growth cycle due to the occurrence of two growth maxima are apparently not due to a similar climatic sequence, for the minimum growth period separating the two maxima in India is apparently in the main not directly connected with climatic change, and the possibility of its being brought about by leaching suggests itself. It is interesting to note in this respect that the decline of growth following good long rains in Kenya may have been due to the same factor. The difference between these periods of minimum growth in the two countries is reflected by the difference in the flowering habits. In Southern India there is usually only a single flowering whereas in Kenya it is normal to have flowerings both at the beginning of the long and of the short rains, although the latter flowering is less pronounced. In Kenya, also, the moister areas tend to suffer from continued small flowerings and usually growth minima have their corresponding flowerings later in the year. It would appear from Indian experience that the mere occurrence of a resting period during which growth is at a minimum is insufficient to cause differentiation of flower bud. It should be remembered, however, that it follows a period of great vegetative activity and that it is of relatively short duration compared to the corresponding minimum growth period in Kenya. It is possible that the tree is exhausted of carbohydrates and there is not enough time for sufficient to be stored up in order to initiate flower bud differentiation. In Kenya, differentiation for the short rains flowering does not usually occur until late in the preceding period of minimum growth and, in fact, would appear to be halted by the onset of the short rains.

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LAND TENURE AND COLONIAL DEVELOPMENT: A REVIEW*

Much has been talked and written about the British colonial policy of holding the tropical dependencies in trust for the native peoples, of raising the standard of education and hygiene, and of encouraging responsibility and self-government. As a long-term policy this is undoubtedly the best, if not the only way, to create a true commonwealth of widely differing races and religions. Progress towards this goal has seemingly been slow in the past, because we tend to think of self-government in terms of Britain and the Dominions, countries in which individual responsibility and national culture have generations of experience behind them. Actually, there is a great danger of moving too rapidly towards self-government, since it is relatively easy to increase the number of schools, to extend the medical and public health facilities, and to give more administrative responsibility to individuals who, through natural ability, have shown themselves fit to lead their fellow countrymen. As the fundamental economy of the Colonial Empire is based on agriculture, it is essential that agriculture progress should go hand in hand with social development. In an agricultural community everyone lives on the land, either directly or indirectly, and in order to have more teachers, more doctors, and improved social services of every kind, more money must come from the products of the soil in order to provide for the upkeep of those members of the community who are not primary producers. Even the butcher, the baker, and the candlestick maker cannot flourish unless the land is producing more than the barest necessities of life.

There are only two ways of increasing the flow of agricultural produce. One is to obtain a higher yield from the same cultivated area and the other is to cultivate a larger area in order to raise the total production. The latter method has been almost universal in the tropical colonies, for, when prices were high it was the easiest way, and when prices were low it was the cheapest. During the twenty-five years between the two recent wars prices of primary agricultural products alternated between unnaturally high figures during short boom periods and "starvation prices" during the more lengthy slumps. Under these circumstances, exploitation of the natural fertility of the soil, without regard to the future, was the natural policy, and agriculturists of all races tried to make as much money as possible while prices were good, in preparation for the next slump.

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* *Land Tenure in the Colonies* by V. Liversage, Cambridge University Press, 1945. 151 pp., price Sh. 7/6d.

It has always been obvious that real progress in tropical agriculture could not be made until there were steadier market conditions, but cut-throat competition between nations has intensified the fluctuations in the past, and it is only now, when the members of the United Nations Organization are discussing their common problems that there is some hope of steadier markets for primary products. Whenever there is a reasonable hope of this, it becomes worth while to invest money in soil improvement, but it would be mere speculation to adopt the more conservative methods of farming unless the system of land tenure were adapted to the conditions. Freehold tenure is admirably suited to the farmer whose policy is to build up the fertility of his soil slowly but steadily, but it also suits the speculator who works the land to exhaustion while markets are favourable, recovers his capital cost with a handsome profit, and thereafter is content to sell the worthless land for a song. So long as individualism is encouraged, exploitation of the land is easy, but this does not mean that ruthless dictatorship is the only remedy. After all, the British Government's declared intention to develop the colonies in trust for the native peoples cannot be implemented unless the agriculturists of these colonies hold the soil in trust for their descendants. Benevolent control over all land should encourage rather than suppress individual efforts towards better farming and higher production per acre, and the slogan that a man's home is his castle can do nothing but harm when it is applied to land utilization.

Now that we are on the eve of more rapid colonial development we must ensure that the land is used to the best advantage, not by exploiting it to produce more money in the near future in order that more bicycles and dry goods may be exported from the industrial countries, but by a long-term policy of agricultural improvement which will steadily, even if slowly, raise the value of the land and the standard of living. There is nothing new in this principle, for it was applied many years ago in building up the fertility of parts of Britain. As an example, one farmer in Scotland was given a piece of land rent free for twenty-five years, on condition that he brought the land into better heart by good husbandry. At the end of that period a small rent was imposed, still on condition that more was put into the land than was taken out of it, and as the years passed the rent was raised in proportion to the man-made fertility of the soil and the economic conditions of the period.

It is unfortunate that the financial success of pioneers in tropical plantation agriculture has given many people in temperate countries a mistaken view of the natural fertility of tropical soils. The West Indian sugar planters, the tea planters of India and Ceylon, and the rubber planters of Malaya, enjoyed, for a time, high profits which led to the false idea that all tropical soils are deep, rich, and inexhaustible. These high profits were not due to heavy yields so much as to the keen demand for the products on the home market, with consequent high prices. The great drop in the purchasing power of the pound during the past fifty years has tended to obscure the fact that, with the cheap labour and equipment of those prosperous days, even a poor soil, with mediocre management, would yield a good profit. When production of these crops became widespread throughout the tropical world, prices dropped through competition, and improved varieties, better methods of cultivation, and regular manuring became necessary for more efficient production. The planters had the advantage of freehold occupation of most estates, and they could build up the fertility of their soils with the confidence of complete ownership. On the other hand, numerous derelict estates show the effects of exploitation on the get-rich-quick system, and the planter had the confidence that no one had the right to interfere.

Mr. Liversage's book reviews the systems of land tenure in the colonies, and it is fortunate that it was published at a time when plans are being considered for more rapid development in the colonial empire. The former trend of administrative policy in some colonies towards owner-occupancy makes the two chapters on that subject of special interest, and evidence is presented to show that the much-vaunted freedom and independence of the owner-occupier is delusive and frequently short-lived. In most countries the owner of an average-sized farm has great difficultly in standing the strain of years of poor yields or low market prices. Debts are incurred, with the land as security, with the result that many farms fall into the hands of money-lenders. This leads to over-cropping, since interest on the mortgage has to be met or rent has to be paid to new owners whose sole aim is to obtain as much interest as possible on the money invested. The author points out that there is a drift back to tenancy even in the United States and Canada, but the new landlords, usually banks or business firms, cannot be expected to appreciate the long-term principles of good husbandry. Speculation in agricultural land is one of the major crimes of man against nature, since quick returns irrespective of distant consequences will impoverish even the best soils.

Individual tenure of native lands has gone further than is generally realized. Among the Kikuyu, Liversage quotes: "signs are not wanting of pretensions to be a landlord", and he notes that the Kikuyu of Kiambu have departed from the normal custom and admit the possibility of a sale outright either of a *githaka* or part of a *githaka*, even although the original meaning of the term was the bush-land over which a clan claimed *common* control. In the cocoa-growing areas of West Africa farming has become so much of a commercial venture that loans, mortgages, and even speculation in land are becoming prevalent. Even although tribal communism had the disadvantage of lack of individual responsibility, it is being replaced by a money-grabbing exploitation which is obviously worse.

Another form of tenure, which is a perpetual and hereditary lease, is called emphyteusis, a term which is found only in the larger dictionaries, such as the *Shorter Oxford English Dictionary* which defines it as "a perpetual right in a piece of another's land". Many Kenya settlers hold their land under a 999-year lease, a common form of emphyteusis, and the occupier is, strictly speaking, an emphyteuta, unless he is sufficiently old-fashioned to prefer the obsolete term emphyteuticary.

The distinction between feudal and tribal systems of tenure is mainly in the degree to which a political system is superimposed upon ordinary tribal practices. In the feudal system "the holding of land is made conditional on the supply of an appropriate number of 'able and efficient men'" for the service of the ruler, to be called upon when required. The two systems have in common the custom that both the feudal lord and the tribal chief allotted land for cultivation and it is interesting to find that, under the manorial system of the middle ages in Europe the tenants' lands "consisted of a number of intermixed strips separated by grass balks, scattered throughout the arable fields so that each holder might have a portion of the various kinds of land".

Labour tenancy is beginning to cause some concern in Kenya, and, as Liversage puts it, "when the time comes to repatriate large numbers owing to the increasing use of European-owned land by closer settlement and more intensive farming, the problem of repatriation may present grave difficulties. The land in their district of origin is likely to be fully taken up and many of the tenants will have lost their social status in their own community. Already blocks of land have had to be provided out of forest reserve or other land for the maintenance of evicted tenants, but obviously this cannot go on indefinitely".

The chapter on the gradual disappearance of tribal tenure shows a similarity between the condition of cattle on the overstocked tribal grazing lands in the colonies and that of cattle in England under the system of open-field commons, before the enclosure. A quotation from Prothero's *British Farming Past and Present* brings out this point: "the live stock that are reared are dwarfed and undersized; they are driven long distances to and fro, so that they have neither rest nor quiet". This irresponsible attitude of cattle owners who use communal grazing is the natural reaction of man to something which does not belong to him alone, and common grazings can be kept in good condition only if some form of agistment fee is charged. By means of grazing fees, stock improvement can be greatly accelerated, since it pays to feed a good animal well, but unthrifty, low-grade stock cannot derive the full benefit from good grazing.

Neither communal nor private ownership has been really successful in the tropics. A community with a definite area of common land rapidly increases in population of man and stock until over-grazing becomes inevitable, and there is a scramble to get as much as possible out of the land without regard for the future. Private ownership may sometimes be successful, but the minority of farmers who are able to keep clear of debt have to suffer from the disastrous results of pressure by money-lenders on those farmers who have incurred debts, since exploitation of the land, with consequent cut-throat market competition, deprives the independent farmer of fair prices. In addition, a system of heritage which permits numerous co-heirs leads to the subdivision of land into parcels which are too small to be worked successfully. Since the original form of tribal tenure resembles in many respects the modern communistic system of Russia, it would have been interesting if the author had included some account of the progress of collectivized farming in the U.S.S.R. and Palestine. If the tribal system could be guided back towards its original principle of mutual aid, it might be possible to introduce a form of collectivized farming which would have something in common with the principles underlying the original tribal customs. Yet, as has been resognized in Soviet Russia, the return to an individual must be based on the amount and quality of his work, and personal reward must be a feature of working for the common good.

After pointing out the weaknesses in both the communal system and private ownership, Liversage states the principles under which a modern policy should be evolved. "A sound system of land tenure must be such as will conduce to the best and most economic use of the land. This consideration demands that the soil be protected from spoliation by occupiers or owners who are seeking quick returns or are forced to let the land down by economic difficulties". He suggests that unsound land-use is caused not so much by low returns as by bad distribution of what returns there are. Some form of public control seems to be the only solution to the problems. It is imperative that land should be protected from misuse, but it is also necessary that the farmer should have sufficient scope for individual initiative. "The tenant's security will not be complete unless he is protected from eviction so long as his use of the land is in accordance with the principles of good husbandry. Security should extend beyond the life of the sitting tenant to his heirs, as an important element in the endeavours of an occupier, particularly towards the latter part of his life, is provision for his family. If he cannot provide for them in the land, he will try the more to provide for them in the bank, and what goes into the bank may come out of the land".

As a concrete suggestion towards control of land use combined with opportunities for individual initiative, the author puts forward the idea that government should buy out existing claims to land and convert free landowners into secure tenants subject to official control. As regards native lands, an alternative suggestion is made that native right-holders would be willing to lease their lands to government for an indefinite period in consideration of an annual cash payment, and that the lands would be let in turn by the government to "cultivating tenants" at a figure sufficient to cover the rent payable to the right-holders and the expenses of estate management. It is unlikely, however, that a right-holder would be willing to accept a rent smaller than the real value of the land, and in order to justify the higher rent to the cultivating tenant it would be necessary to raise the value of the land by capital works such as drainage and irrigation. Whatever the plan, it is almost certain that government would be involved in a considerable outlay per acre, and that this capital would not be recovered except possibly over a very long period.

The success of war-time emergency control farming practice and of marketing in the United Kingdom has shown that, even in a country where independence has been encouraged in the past, much good can be done to the individual by control measures for the common good. It can hardly be denied that in many parts of East Africa a state of emergency exists, and that in others it will develop in a relatively short time. It is clear that governments cannot waste much more time and money in *advising* farmers to desist from exploiting the fertility of the soil.

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INDEX TO VOLUME XI—1945-46

PAGE

Agricultural—
  Extension methods amongst African peasant farmers (G. B. MASEFIELD) .. 214
  School, Bukura, Nyanza (E. L. BRADFORD) .. 162

Agriculture—
  European, in Kenya, what is wrong with? (V. LIVERSAGE) .. 80
  in semi-arid areas .. 133

Antestia spp. recent investigations in Uganda (T. H. C. TAYLOR) .. 47

Bags, prevention of waste of (reprint) .. 64

Bukura agricultural school, Nyanza (E. L. BRADFORD) .. 162

Bush—
  control and deferred grazing (R. R. STAPLES) 43
  eradication (poisoning and cutting) .. 40
  remover (photos, G. COLVILE) .. (17)

Camphor production in East Africa (A. G. G. HILL) .. 148

Cattle—
  feeding (review) .. 193
  growth rates of hair on grade European and indigenous breeds (M. H. FRENCH) .. 181
  progress of native (selection and management) at Sangolo, Kavirondo (R. H. CAMERON) .. 20

Coffea arabica—
  growth and bearing habits in Kenya and South India (R. W. RAYNER) .. 251
  mulching (S. M. GILBERT) .. 75

Compost factory (J. E. MACARTNEY-SNAPE; letter) 222

Composting, the Maya Das method .. 157

Cotton grower, day in the life of (B. K. KAUMI) 37

Cultivator, Duckfoot (letter, E. F. PECK) .. 36

Cupressus macrocarpa canker (R. M. NATTRASS) 82

Cynodon plectostachyum composition .. 100

Cypress pruning (letter, G. W. HUMMEL) .. 11

Dairy farming in Northern Sudan (J. W. HEWISON) .. 104

D.D.T. for mosquito control (reprint) .. 188

Education, native agricultural, Bukura, Nyanza 162

Elephant grass as soil improver .. 4

PAGE

Flood regimes of three Tanganyika rivers, recent alterations (A. H. SAVILE) .. 69

Food plants, origin of some East African (P. J. GREENWAY) .. 56

Goat, the; friend or foe? (C. MAHER) .. 115

Golf greens and lawns in East Africa (M. D. GRAHAM) .. 94

Grass—
  composition of different types of star .. 100
  leys as soil improvers in Kavirondo .. 4
  leys on Kinangop (J. W. ETHERINGTON) .. 67

Grasses of Uganda (review) .. 28

Grazing, *see* Pasture.

Hides and skins industry, notes on the (M. H. FRENCH) .. 238

Insemination, artificial (review) .. 193

Kenya agriculture, European, what is wrong with? .. 80

Land tenure (review) .. 255

Lawns in East Africa (M. D. GRAHAM) .. 94

Leys, *see* Grass.

Live stock improvement in relation to environment (review) .. 121

Locust campaign, use of transport and poison bait in (R. J. M. SWYNNERTON) .. 224

Locusts—
  destruction by beating (R. W. COLLETT) .. 35
  international control (H. J. BREDO) .. 12

Maize, green, and millets, green; composition and feeding values (M. H. FRENCH) .. 159

Murram blocks (J. F. LOW) .. 145

Pasture—
  bush control and deferred grazing .. 43
  carrying capacity at Serere (R. K. KERKHAM) 170
  mineral deficiencies and excesses in (M. H. FRENCH) .. 189

Pennisetum purpureum as soil improver .. 4

Pigs, slaughter-house waste as food for .. 29

Plants, what they do with their materials (reprint) .. 186

Ploughing, deep (letter, G. W. REYNOLDS) .. 11

PAGE

Population problems of Tanganyika Territory (C. GILLMAN) 86

Potatoes—
  cutting and treatment of seed (R. M. NATTRASS) 83
  effects of day-length on yield (R. W. RAYNER) 25

Poultry, slaughter-house waste as food for .. 29

Rainfall, wasted, and crop production (J. T. PURVIS) 110

Rice-milling methods (R. I. BUTLER) 17

Seed-grower's notebook (F. HAWKINS) 32

Semi-arid areas, problems of (J. GLOVER) .. 133

Silverfish control (reprint) 55

Sisal, spacing of (G. W. LOCK) 247

Slaughter-house waste products as food for pigs and poultry (M. H. FRENCH) 29

Soil—
  fertility 1
  fertility with particular reference to African farmers (M. D. GRAHAM) 3
  moisture 131
  structure, effect of rotations in Kavirondo .. 3

Star grass, composition of different types (M. H. FRENCH) 100

Strophanthinum (P. J. GREENWAY) 184

PAGE

Sudan, Northern, dairy farming in 104

Sweet-potato storing in Zanzibar (G. E. TIDBURY) 34

Timbers, East African, insect damage to (review) 192

Tree poisoning 40

Tung tree, improved planting material of (C. C. WEBSTER) 165

Vegetable seeds, notes on 32

Water—
  conservation 110
  conservation for storage underground (F. GRUNDY) 139
  conservation for storage underground (letter, C. MAHER) 221
  warning from 65

Water-finding—
  modern methods 195
  principles governing (E. PARSONS) 197

Weed trees, eradicating (H. K. LONG) 40

Wheat—
  experiments, Northern Province (N. R. FUGGLES-COUCHMAN) 231
  large-scale production in Oldeani, Tanganyika Territory, 1943 and 1944 (C. REDFEARN and N. R. FUGGLES-COUCHMAN) 122

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